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INTRODUCTION

Hemp dogbane (Apocynum cannabinum) is becoming more troublesome in the western corn belt. Hemp dogbane was ranked as the number one perennial weed problem in Nebraska (Evetts, 1977) in a survey of perennial weed problems of states in the upper midwest. Hemp dogbane was the second most troublesome perennial weed in Kansas following climbing milkweed. Hemp dogbane ranked as the number one perennial broadleaf weed in Iowa, following yellow nutsedge and quackgrass as the most troublesome perennial weeds.

In light of recent observations of hemp dogbane becoming a major row crop weed problem, it is interesting to note that Hitchcock and Clothier (1898) stated that milkweed and hemp dogbane, although hard to kill when established, did not tend to become troublesome weeds. Kiltz (1930) also noted that hemp dogbane was most serious as a weed pest in small grain fields and meadows. This contradicts present notions of hemp dogbane being less able to compete in small grain and hay crops than in row crops.

The objective of this study was to determine the effects of soil tillage on hemp dogbane growth and development. Hemp dogbane biology, carbohydrate and lipid analyses, and herbicidal control were pursued supportive of this goal.

LITERATURE REVIEW

Research directed towards the effects of current corn belt tillage practices on perennial weeds is limited. Data reported usually involve tillage by herbicide interaction studies which report perennial weed problems arising as an observation secondary to other data collected. Work on clean-fallow tillage to control perennial weeds has been widely published. Seasonal carbohydrate levels in perennial organs, as well as effects of tillage on these carbohydrate levels, have been reported for some perennial weeds. Herbicide control of hemp dogbane and other perennial weeds has been fairly well documented. Light and soil temperatures have been shown to play a role in bud dormancy of perennial weeds.

The Biology of Hemp Dogbane

Hemp dogbane seedlings became perennial 41 days after emergence (Robison and Jeffery, 1972). Frazier (1944) delineated the rapid spread of the hemp dogbane root system. He reported hemp dogbane plants gained a radial spread of 3.35 m and a vertical spread of 2.13 m within 28 weeks after seedling emergence. The same plants two years later had gained a radial spread of 5.39 m and a vertical spread of 4.27 m (Frazier, 1945).

Hitchcock and Clothier (1898) described a horizontal

root of hemp dogbane which was traced 8.8 m in length without finding the end.

Frazier (1944) noted that hemp dogbane vertical roots had penetrated approximately 2.1 m within 7 months of the growing season. Small feeder roots that appeared to be in a favorable position in relation to soil moisture and plant nutrients grew extensively and became perennial laterals. Vertical shoots were derived from adventitious buds on lateral roots. Adventitious buds immediately gave rise to shoots when located near the soil surface, but ascended through rhizome extension when buds originated deeper in the soil profile. At no time were the lateral roots of the first order found to turn downward and become vertical roots. Vertical roots descending as feeders always originated from secondary and tertiary lateral roots. This exemplifies the aggressive creeping root system of hemp dogbane.

Schultz and Burnside (1979b) noted that hemp dogbane competed less favorably with corn than with sorghum or soybeans. Significant yield reductions from increasing hemp dogbane populations were noted in dryland sorghum, irrigated and dryland soybeans, but little reduction in irrigated and no reduction in dryland corn was observed. They also found crown and lateral root regeneration through bud activity was highest in root sections exhumed during February through April. Regenerative capacity decreased until reaching a low in September, followed by moderate increases through October and

November. Root regenerative capacity could be altered, however, due to environmental conditions as was noted due to defoliation by insects and hail. Phenological data showed time intervals between hemp dogbane growth stages were dependent on environment and cropping systems.

Soil Tillage and Perennial Weeds

Triplett and Lytle (1972) found that hemp dogbane became a significant problem in some no-tillage plots after several years of continuous corn. None of the soil-applied or early postemergence herbicide treatments provided satisfactory control. Little or no invasion of hemp dogbane occurred into tilled areas. The pattern of infestation seemed to indicate that hemp dogbane colonies grew from individual plants in plots where seedlings were able to become established due to certain herbicide programs. After establishment, hemp dogbane was not affected by herbicides used and colonies expanded in the absence of competition from other weed species. Canada thistle (Cirsium arvense) and common dandelion (Taraxacum officinale) had also increased in no-tillage plots and were spot treated separately.

Sanford et al. (1973) noted that yellow nutsedge (Cyperus esculentus) reduced double crop soybean yields with no-tillage methods. But Triplett (1978) did not find that perennial weed species became troublesome with 4 years of

no-tillage double crop soybeans grown in wheat stubble. Perennial weed infestations that arose could easily be handled by spot treatments of herbicides such as glyphosate. Pollard and Cussans (1976) noted that perennial species such as Rumex spp., common dandelion, field bindweed (Convolvulus arvensis), and quackgrass (Agropyron repens) became more prevalent where direct drilling of cereal crops was used. Of these, only quackgrass was considered important agriculturally.

Froud-Williams et al. (1981) reviewed changes in weed floras associated with reduced cultivation systems. They cited several references where perennial species, both monocotyledons and dicotyledons, increased in the absence of cultivation. Many of these referred to Agropyron repens, but Arrhanatherum elatius, Cirsium arvense, Rumex spp., and Convolvulus spp. were also noted important in some areas. The general consensus was that perennial grasses might be the greatest threat to the adoption of minimum cultivation systems, but that glyphosate appears to have alleviated many of the troublesome perennial grasses. Other rhizomatous species and creeping perennials remained localized, although the number of perenniating organs such as rhizomes may increase in the undisturbed situation. Incidences where herbicidal control of annual species along with the absence of cultivation led to an increase in perennial weeds that were checked with

glyphosate were cited. Literature cited suggested that reduced cultivation would favor rhizome and stolon bearing perennials over annuals, but that herbicide selection pressures will result in selecting for weed communities poor in species diversity but high in the density of individuals. Such individuals would likely be larger than occur in more competitive situations. Hemp dogbane appears to meet these criteria.

Evetts and Burnside (1974) compared common milkweed (Asclepias syriaca) root systems under a tilled cropping system and a smooth brome (Bromus inermis) field receiving no tillage. Although plant populations were similar between the two fields, the root diameter of milkweed tended to be larger in the tilled fields, especially in the upper 60 cm. The plow layer of the tilled field, though having the largest maximum root diameter, had a higher percentage of roots less than 2 mm in diameter than did the nontilled field. The tilled field had a higher percentage of smaller (less than 2 mm) roots within the plow layer and a higher percentage of larger roots developing just below this zone than throughout the rest of the tilled field soil profile. There also were significantly more roots under each square meter in the tilled field than in the smooth brome field. They theorized that perhaps roots in the tilled field areas have enlarged to enhance food storage and reproductive potential in response

to repeated tillage.

Timmons and Bruns (1951) studied the frequency and depth of shoot cutting cultivation treatments required to eradicate several creeping perennial weeds. Hemp dogbane could be eliminated within 3 years by wheel hoeing at a 2.54 cm depth at 2- and 4-week intervals requiring an average of 31 and 17 operations, respectively. Wheel hoeing every 6 weeks showed little effect on hemp dogbane the first 2 years, but was quickly eliminated in the third year when a 2- and 3-week interval wheel hoeing schedule was resumed. Spading to a depth of 12 inches every 6 weeks eliminated dogbane within 3 years. Eighteen and 15 duck-foot cultivator treatments at 3- and 4-week intervals, respectively, were required to eradicate hemp dogbane during the third season of bare fallow.

The longest interval allowable for shallow wheel hoeing was 4 weeks. Longer intervals between shoot cuttings generally required longer periods to eradicate hemp dogbane than did shorter intervals. The longer effective intervals required fewer overall operations however. Greater depth of shoot cuttings with the duck-foot cultivator, plow or spade lengthened the effective interval between cultivations required to eradicate hemp dogbane, but there was no practical advantage to cultivating deeper than 3-4 inches.

Perennial Weeds, Tillage, and Carbohydrate Levels

Studies have been performed on perennial weeds examining cultivation and carbohydrate levels in relation to plant growth. Carbohydrate levels in perennial reproductive structures follow a general trend of depletion during early season vegetative growth until positive net photosynthate accumulation levels are obtained. From this seasonal low, carbohydrate levels generally begin to build as excess photosynthate assimilates are stored for future regenerative needs. The seasonal low generally correlates to the flowering stage of growth for perennial plants.

Gerhardt (1929) found the seasonal low in milkweed roots occurred during flower bud formation in June and July with sucrose and starch levels being inversely correlated. Arny (1932) found varying degrees of seasonal trends with five perennial weed species observed. Quackgrass, leafy spurge (Euphorbia esula), field cress (Nasturtium austriacum), sow thistle (Sonchus avensis) and Canada thistle were examined for carbohydrate and nitrogen levels. All except quackgrass experienced sharp declines in carbohydrate levels during early season vegetative growth. Perennial broadleaf weeds showed varying degrees of expected seasonal trends with seasonal lows occurring when plants were in bloom. Ilnicki and Fertig (1962) found similar seasonal trends with horsenettle (Solanum carolinense).

Higher carbohydrate levels have been found in root segments below the plow layer for horsenettle (Ilnicki and Fertig, 1962), hemp dogbane (Schultz and Burnside, 1979b), common milkweed (Evetts and Burnside, 1974), and field bindweed (Frazier, 1943; Gigax, 1978).

Cultivating or clipping plants during flowering stages to deplete carbohydrate storage, or spraying with systemic herbicides at this stage to get maximum translocation to underground root systems during carbohydrate storage buildup have been studied. Arny (1932) found that cutting Canada thistle during full bloom delayed growth the following year but did not result in lowering carbohydrate reserves in storage roots. Evetts and Burnside (1974) observed numerous common milkweed shoots that had arisen from a 30-107 cm depth, indicating that deep fall plowing would not be satisfactory for the control of milkweed even if the fragments in the plow layer were killed. They also questioned the ability of herbicides to translocate deep enough to prevent emergence from lower root areas. Ilniki and Fertig (1962) noted the ability of 5 and 10 cm horsenettle root segments to produce new shoots from depths of 40 and 50 cm, respectively. This, coupled with higher starch levels in lower root segments, indicated that no amount of disking or plowing would control horsenettle.

Bakke et al. (1939) found maximum carbohydrate reserves

in the lower root depths of field bindweed were depleted after two full seasons of continuous fallow. They noted the small quantity of carbohydrate reserve needed to regenerate new growth and the slow removal of reserves from the lower levels owing to the persistence of field bindweed. Bakke et al. (1944) noted that despite the higher concentration of available carbohydrates in lower field bindweed roots, absolute carbohydrate levels were greater in the upper soil layers due to the higher quantity of roots in that zone. He also noted that roots tended to die first in the upper soil horizon with continued clean-fallow tillage, suggesting that deeper root carbohydrates could not replenish the upper strata rapidly enough to keep the roots alive. There was no consistent depletion of carbohydrates at lower depths to substantiate this however.

There was a very rapid recovery of carbohydrate reserves following new spring growth of field bindweed (Bakke et al., 1939) relative to other perennial weeds. This indicated the need for early fallow treatments to insure control. Barr (1940) found that early cultivation at emergence had no greater effect than less frequent cultivations in reducing carbohydrate levels in field bindweed. However, he did show depletion of carbohydrates with continued cultivation. Similar depletion of carbohydrates with cultivation has been shown for whiteweed (Cardara draba var. repens) (Barr, 1942).

Carbohydrate Levels and Herbicidal Control of Perennial Weeds

Gigax (1978) found a close association between field bindweed root carbohydrate content and 2,4-D accumulation. Whether carbohydrate and herbicide movement was due to an active sink or independent but simultaneous activity could not be determined. Glyphosate followed carbohydrate movement trends in June but not throughout the rest of the season. McWhorter (1974) found that johnsongrass (Sorghum halepense) rhizome carbohydrate levels were replenished shortly after emergence. Control measures such as clipping or herbicide applications were advocated at this time. He indicated that dalapon might give best control applied before flowering, before carbohydrate levels were replenished in the rhizomes of johnsongrass. Cords and Badiei (1964) found no correlation between food reserves in the roots and the response of salt cedar (Tamarix pentandra Pall.) and Woods rose (Rosa woodsii Lindl. var. ultramontana (Wats.) Jeps.) to silvex and 2,4,5-T. They cite literature supporting and disputing carbohydrate correlation with herbicide translocation.

Studies have shown that glyphosate and 2,4-D appear to move in the phloem of hemp dogbane (Wyrill and Burnside, 1976; Schultz and Burnside, 1980). The potential for improved control of hemp dogbane by applying herbicides during periods of greater metabolic sink activity was discussed. Schultz

and Burnside (1980) suggested that root buds of hemp dogbane were not active sinks during the fall while carbohydrates are being translocated to the roots. Lethal amounts of herbicide may not accumulate in these buds, preserving regrowth potential. This effect has been shown for quackgrass (Claus and Behrens, 1976).

The use of surfactants with glyphosate to enhance control of hemp dogbane was not recommended due to variable results (Wyrill and Burnside, 1977). Absorption of glyphosate through the plasmalemma may be more of a potential barrier to effective hemp dogbane control than translocation of glyphosate (Wyrill and Burnside, 1977; Richard and Slife, 1979). More effective control of hemp dogbane was noted when glyphosate was applied during the early bud stage as opposed to applications made earlier during vegetative stages or later during late-flower stages by Barnes and Brenchley (1972). They also noted improved effectiveness of glyphosate due to mowing dogbane plants through delayed maturity and stimulation of underground buds to initiate growth resulting in more plants to treat. Glyphosate applications to regrowth were more effective than treatments applied earlier in the season.

Dicamba and 2,4-D were more effective applied to hemp dogbaen in late September than herbicides applied in June or October (Roeth, 1977), but relative plant development was not

discussed. Robison and Jeffery (1972) found phenoxy and/or dicamba herbicide treatments gave more complete control applied in September when hemp dogbane crown and lateral root buds were swelling than in June at the early bud stage. Although effective control could be obtained from June applications, fall applications were recommended because of decreased injury potential to the crop. Fawcett and West (1978) found glyphosate, 2,4-D, and dicamba gave poor control of hemp dogbane following corn harvest due to mechanical damage disrupting translocation to the roots and reduced spray interception. Schultz and Burnside (1979a) found that glyphosate generally provided better hemp dogbane control than did 2,4-D. Hemp dogbane seedlings were shown to have poor emergence capabilities (Robison and Jeffery, 1972), poor emergence under moisture stress (Evetts and Burnside, 1972a), and were susceptible to most soil-applied herbicides (Evetts and Burnside, 1972b).

Lipids, Latex, and Energy Reserves in Plants

Laticiferous plant systems are generally considered to be an excretory and storage system for secondary metabolites. Latex apparently does not act as a cellular energy reserve (Bonner and Galston, 1947). The starch that accumulated in laticifers of Euphorbia heterophylla L. and E. myrsinites L. was not depleted in dark-grown seedlings, whereas the starch

in stem and leaf parenchyma was mobilized (Biesboer and Mahlberg, 1978). The starch content of latex in light-grown plants remained constant during development of floral primordia, flowering, and subsequent fruit formation.

Acetone and benzene extraction of hemp dogbane lipid materials has been performed (Minshall, 1957). A relatively low percentage of the lipid extraction was found to be rubber. Combined extracts ranged from 15 to 20% dry weight. Members of the Asclepiadaceae and the Apocynaceae families are considered to be branched or unbranched nonarticulated laticifers (Metcalfe, 1967). No literature dealing specifically with hemp dogbane and its laticifer structure was found.

Photoperiod and Light Responses in Perennial Weeds

Light exposure and dormancy break in annual weed seeds was first suggested by Sauer and Struik (1964) in relation to soil disturbances. Others have reported dormancy break in annual weed seeds through light exposure (Taylorson, 1970, 1972; Wesson and Wareing, 1969). Considerable work has been done on the effects of light on perennial weeds. Longer photoperiods produced heavier rhizomes (Williams, 1971) and more numerous and thicker rhizomes in quackgrass (Palmer, 1958). Light effects on quackgrass rhizome bud dormancy through emerged shoot apical dominance were reported (Leakey et al., 1978). Reduced light intensities increased shoot

production from quackgrass rhizomes (Palmer, 1958; Williams, 1970).

Longer photoperiods increased rhizome production of emerged cogongrass (Imperata cylindrica) (Patterson et al., 1980), and reproductive development of yellow (Cyperus rotundus (Jansen, 1971) and purple nutsedge (C. esculentus (Wills, 1975). Williams (1978) found photoperiod length did not effect the partitioning of dry matter between shoots, roots, rhizomes, and tubers of purple nutsedge. Patterson (1982) found shading decreased the partitioning of dry matter into tubers and rhizomes relative to leaves in purple and yellow nutsedge.

Jansen (1971) mentioned that yellow nutsedge growth is probably not initiated from nutlets or seeds until late spring in response to warming temperatures that do not occur until photoperiods are longer than 14 hours. After that, increasing daylengths promoted shoot and rhizome growth. An extensive study on the dormancy of western ironweed (Vernonia baldwini Torr.) is given by Davis and McCarty (1966). Several factors such as apical and shoot dominance, pod maturity, and temperature-related blocks in relation to bud dormancy on ironweed rhizomes were noted. Spring dormancy break was observed when maximum daily soil temperature approximated 15°C at the 5-inch depth. Literature citing winter dormancy in johnsongrass rhizomes with reference to

soil temperature was reviewed by Monaghan (1979).

Other studies have shown differences in the seasonal regenerative capacity of the rhizomes of quackgrass (Johnson and Buchholtz, 1962), ironweed, and for root sections of leafy spurge (Monson and Davis, 1964) and hemp dogbane (Schultz and Burnside (1979b). These studies dealt with the ability of exhumed rhizomes and root segments to produce shoots without regard to the possibility of photoperiod effects or factors that would release dormant buds following winter resting stages.

Phytochrome levels were found to be highest in the young meristems of johnsongrass rhizomes (Duke and Williams, 1977), tips of Helianthus tuberosus tubers, and buds of Trillium rhizomes (Koukkari and Hillman, 1966). Phytochrome was also found to control basal bulb formation in purple nutsedge (Chetram and Bendixen, 1974). Duke and Williams (1977) attempted to provide a basis for examining photomorphogenic responses of johnsongrass rhizomes to light. Bonnett (1972) related phytochrome regulation to the promotion of continued elongation and shoot emergence from field bindweed buds on lateral roots just below the soil surface. Far red light or darkness stimulated growth of purple nutsedge rhizomes (Alexio and Valio, 1976). No substantial literature was found in regard to photoperiodism or phytochrome response in relation to the spring dormancy break (winter resting period) of perennial plants.

MATERIALS AND METHODS

Field studies examined the effects of soil tillage on an established stand of hemp dogbane and on the establishment of several perennial weeds. Carbohydrate and lipid levels of hemp dogbane were analyzed for seasonal effects, and effects due to seedbed tillage. Herbicidal control of hemp dogbane was studied and the relationship of photoperiod length on seasonal dormancy of hemp dogbane was explored.

Established Hemp Dogbane and Soil Tillage

A field study was initiated in 1979 to evaluate soil tillage effects on hemp dogbane at Cumberland, Iowa. A farmer-cooperator was used to enable finding a site with a relatively uniform hemp dogbane population over a 2-acre area. The soil type was a Judson silt loam alluvial fan derived from surrounding Marshall-Sharpsburg association slopes. The field had been tandem disked before planting in 1978, but had been moldboard plowed 20 to 25 cm deep, disked, harrowed, then planted and usually cultivated twice in seasons prior to 1978. Herbicide programs had been alachlor or butylate with cyanazine and/or atrazine with occasional early post 2,4-D applications. The field had been in continuous corn since 1973.

The experimental design was a randomized split-plot design with two row cultivation treatments nested within

17 seedbed tillage treatments.

Seedbed tillage treatments were replicated four times. Whole plots were 3.9 m wide and 18.3 m long. Subplots were 3.9 m wide by 9.1 m long, dividing the whole plots in half. Borders 4.6 m long were left between whole plots to allow movement of farm machinery between ranges of the test area. Metal plates were buried 46 cm deep as benchmarks at all four corners of the test area to allow plot restaking in the same location from season to season. Continuous corn was grown in 96.5 cm row widths. Hemp dogbane populations were assessed by counting shoots the full length of each plot between two corn rows. Base line populations were obtained by counting crowns from the 1978 season on May 5, 1979 before emergence began.

Seedbed tillage treatments consisted of three years of continuous tillages performed in the spring or the fall, or a tillage rotation with less severe seedbed tillage in subsequent seasons performed only in the spring. Fall treatments for 1978 were performed in the spring of 1979 so fall tillage data by December 1981 is actually two years of fall and one of spring tillage. Seedbed tillage was no tillage, tandem disking 15 cm deep at 7.2 km hr^{-1}, chisel plowing (curved shank) 25 cm deep at 7.2 km hr^{-1}, and moldboard plowing (four 36 cm shares) 19 cm deep at 5.6 km hr^{-1}. Row cultivation was performed with a Lilliston rolling

cultivator operated 4-5 cm deep at 10.5 km hr^{-1}. All seedbed tillage treatments, except no tillage, were disked 8 cm deep at 7.2 km hr^{-1} before planting in the spring.

Preemergence herbicide applications of alachlor (3.9 kg ha^{-1}) + cyanazine (2.3 kg ha^{-1}) + atrazine (1.1 kg ha^{-1}) were applied in 280.5 liter ha^{-1} water and 2.1 kg cm^{-2} pressure at 6.57 km hr^{-1}. Good to excellent control of annual broadleafs and grasses resulted in limiting species diversity essentially to field corn and hemp dogbane.

Observations were made on emergence, ground cover as a visual estimate of biomass, flowering, pod set, and maturation of hemp dogbane throughout each season. A Campbell Scientific CR21 Micrologger was used to monitor rainfall, soil, and air temperatures in 1980 and 1981. Soil temperatures were monitored at 10.16 cm depths in no tillage, spring disk, spring chisel, and fall plow and at 30.48 cm in no tillage and fall plow treatments. Air temperature was monitored at 1.52 m above the soil surface. Daily average, maximum and minimum temperatures were tabulated. The root development of hemp dogbane was examined in 1980 and 1981. In 1980, both spring and fall continuous tillage treatments were examined on April 23. A section 1 m wide by 2 m long and 0.6 m deep was excavated by hand in reps 2 and 4. In 1981, all 4 reps of only the continuous spring tillage treatments were excavated. A trenching machine was used to dig a trench

0.8 m wide by 1.5 m deep across the entire width of the plot.

Table 1 is a data log for cultural practices and data collection in 1979-1981. Population data were analyzed through individual t-tests. Growth and development observations were analyzed through general linear models regression for unbalanced designs as occurred in 1980 due to some tillage rotations not differing until the third year. Growth and development observations in 1981 were analyzed through analysis of variance tests. Both 1980 and 1981 means were compared through Duncan's multiple range tests at the 5% level.

Perennial Weed Establishment and Soil Tillage

A tillage study was initiated at Nashua, Iowa in 1977 on a Kenyon loam soil (pH 6.5, OM 6.5). Plots were 0.4 ha and replicated 3 times. The experiment was conducted as a split-plot design with seedbed tillage treatments of no-tillage slot plant, till-plant, chisel plow, and moldboard plow nested within crop rotations. Till-plant was performed using a Buffalo Till planter with sweeps in front of each planter unit to split the old crop row ridge throwing crop residue between rows leaving a bare ground seedbed within the row approximately 25 cm wide.

Crop rotations consisted of continuous corn and two

Table 1. Data log for pertinent cultural practices and data collection for the established hemp dogbane study, Cumberland, Iowa, 1979-1981

Date			Cultural practice or data collection performed
1979	May	5	1978 base line counts, spring seedbed tillage
		10	Disked, planted corn
		13	Preemergence herbicide application
	June	17	Row cultivated
		30	Lay-by row cultivation
	November	20	Fall seedbed tillage
1980	April	23	Trenches dug for root study, spring seedbed tillage
	May	8	Disked, planted corn, preemergence herbicide application
	June	24	Flowering notes (whole plots), population counts
	July	7	Ground cover, plant height notes (whole plots)
		9	Row cultivated
	November	11	Fall seedbed tillage
1981	April	5	Spring moldboard plow and chisel plow
		21	Spring disk
	May	7	Disked for planting, planted corn
		16	Preemergence herbicide application
	June	20	Flowering, ground cover, plant height notes (split-plots), row cultivation
	July	7	Flowering, ground cover, plant height notes (whole plots)
	August	8	Pod set notes (whole plots)
	September	5	Maturation notes
		27	Population counts
	November	6	Trenches dug for root study

corn-soybean rotations. Corn-soybean rotations were duplicated so that, in any given year, both corn and soybean phases of a rotation sequence were planted. As a result, tillage treatments had 9 observations and crop rotation sequences had 12 observations per treatment. All plots were row cultivated twice each year with a Buffalo-Till cultivator.

Preemergence herbicides were applied to control annual weeds at 2.6 kg cm^{-2} in 252 liters ha^{-1} water. Continuous corn received alachlor (2.2 kg ha^{-1}) + atrazine (2.0 kg ha^{-1}). Corn in corn-soybean rotations received alachlor (2.2 kg ha^{-1}) + cyanazine (2.0 kg ha^{-1}). Soybeans received alachlor (2.2 kg ha^{-1}) + metribuzin (0.5 kg ha^{-1}). Glyphosate was applied as a 33% solution through a rope wick applicator over soybeans in 1979 and 1980.

Perennial weeds evaluated were hemp dogbane, American germander (Teucrium canadense), yellow nutsedge, common milkweed, and Canada thistle. Counts were taken on June 19, 1980 and June 25, 1981. Four passes were made through each plot counting perennial weeds in a swath 1.5 m wide for a total of 0.04 ha counted. Analysis of variance and Duncan's multiple range tests were performed on treatment effects.

Hemp Dogbane Total Nonstructural Carbohydrate and Lipid Analysis

Carbohydrate and lipid levels were monitored in an established stand of hemp dogbane. Samples were taken from the test area described in the established hemp dogbane and soil tillage section. Samples were collected from two no-tillage areas throughout the 1980 and 1981 growing season. Samples were collected from 2 or 4 replications of each continuous spring and fall seedbed tillage treatment on April 23 and November 6, 1980 and on May 7 and November 5, 1981. Samples were collected by spading out crown root sections 30 cm deep. Five crowns were randomly selected from each replication, bagged and put on ice until reaching the laboratory where they were stored at $-18^{o}C$ until analyzed.

Samples were analyzed for total nonstructural carbohydrate (TNC) and gross lipid levels. Reducing, nonreducing and the sum total ethanol soluble carbohydrates, as well as starch and the sum TNC levels were calculated on a percentage dry weight basis. Lipids were examined as ethanol soluble, ethanol insoluble, and the sum total lipid levels, also expressed as percentage dry weight.

Thin slices were taken from a crown area 8-15 cm below the soil surface, and pooled from each of 5 crowns in a treatment sample. Slices were homogenized in a Virtis tissue homogenizer in 85% aqueous ethanol. The filtrate and rinsate were removed under suction, combined and reduced in

volume with a flash evaporator at 35°C, and brought up to 50 ml in 85% ethanol.

A 10-ml aliquot of ethanol extract was triple washed in petroleum ether (B.P. 60-70°C) to remove lipids, and the ether partitioned in a separatory funnel. The ethanol insoluble residue was soaked in excess petroleum ether for 30 minutes and the filtrate and rinsate recovered under suction. The ether was dried under a stream of nitrogen in preweighed aluminum weigh pans and further dried 24 hr under a vacuum broken with nitrogen at 30°C. The ethanol and ether insoluble residue was dried in a forced air oven at 70°C for 24 hr. Dry weights were taken on the residue and lipids and the lipids discarded. Residue subsamples were weighed on an analytical balance and placed in test tubes for starch analysis. The remaining ethanol extract was brought to 0.02% NaN_3 w/v and stored under nitrogen at -18°C, along with the preweighed residue samples until further analysis.

All colorimetric and enzyme digests were carried out on duplicate samples. Total ethanol soluble carbohydrate levels were determined by the phenol-sulphuric acid colorimetric method (Dubois et al., 1956). Ethanol soluble reducing sugars were determined by the Nelson-Somogyi colorimetric method (Hodge and Hofreiter, 1962). Preliminary starch determinations on ethanol insoluble residue were made with α-amylase (1 ml of 20 mM phosphate buffer pH 7.0 with

approx. 30 units of Sigma Type I PMSF treated porcine pancreatic α-amylase, 10 mM NaCl, and 0.02% NaN_3 w/v) with Nelson-Somogyi colorimeter reducing sugar equivalent determinations. Amyloglucosidase (Sigma from Rhizopus mold, approx. 30 units in 1 ml of 20 mM acetate buffer, pH 4.8 with 0.02% NaN_3 w/v) followed by glucose determinations made with glucose oxidase (Fleming and Pegler, 1963) (Sigma Type V glucose oxidase from Aspergillus niger, Sigma Type II peroxidase from horseradish, Sigma o-dianisidine hydrochloride) was also used for starch determinations.

The α-amylase method was used because of slightly higher yields despite reports of spuriously high readings with unpurified amyloglucoidase from β-glucanase contamination (MacRae, 1971). Residue samples in 1 ml phosphate buffer were boiled 60 minutes, cooled, 1 ml enzyme buffer solution added and incubated for 60 hr at 50°C in a water bath with occasional shaking. Samples were then boiled 15 minutes to precipitate proteins, centrifuged, and diluted aliquots taken for reducing sugar determinations.

Dormant and flowering stage no-tillage carbohydrates in 1981 were further examined by qualitative analysis. Ethanol soluble carbohydrates and starch digests were separated by paper chromatography developed using an ethyl acetate:pyridine:water (10:4:3 v/v/v) solvent system (Hough and Jones, 1962). Reducing and some nonreducing sugars were

detected with an ammonical silver nitrate spray (Trevelyan et al., 1950). Ketose and oligosaccharides containing ketose groups were detected by the Seliwanoff's resorcinol method (Hattori and Shiroya, 1951). Residues, starch digests, and ethanol soluble carbohydrates were spot checked for fructose and fructosans by the Roe colorimetric method (Davis and Gander, 1967).

Ethanol soluble carbohydrates were separated using polyacrylimide gel (Biogel P-2, 200 mesh) molecular sieve chromatography collecting 1 ml fractions with a flow rate of 5.5 cm hr^{-1} through a column bed of 1.0 by 90.0 cm at 25°C using a 0.02% w/v NaN_3 aqueous solvent system. Carbohydrates were determined with the phenol-sulfuric colorimetric method, peaks combined, and sugars identified by paper chromatography as discussed earlier.

These same 1981 dormant and flowering no-tillage sampling date ethanol extracts were analyzed for glucose with glucose oxidase, sucrose by invertase (Sigma Type VII from bakers yeast, approx. 40 units in 2 ml 20 mM acetate buffer pH 4.8 incubated at 55°C for 1 hr and read with the Nelson-Somogyi colorimetric method), reducing and total ethanol soluble carbohydrates. Two crown and lateral root samples from the trenches dug November 5, 1981 were examined for carbohydrate levels by depth.

Seedbed tillage treatment carbohydrate and lipid levels

were compared with Duncan's multiple range tests and seasonal trends examined by stepwise orthogonal contrasts. Correlation analyses were performed comparing lipid and carbohydrate levels.

Herbicidal Control of Hemp Dogbane

Hemp dogbane control with broadcast herbicides in corn

Hemp dogbane stands were sprayed with postemergence herbicides in corn on June 21 or September 11, 1979. Plots were visually evaluated on June 28, 1980. All treatments were replicated four times on 3.0 by 10.1 m plots. Applications were made with hand sprayers equipped with TeeJet 8003 flat fan nozzles delivering 280 liters ha^{-1} at 2.1 kg cm^{-2}. On July 21, 1979, hemp dogbane was at the late bud to early flower stage of growth, air temperature was 24°C and corn was at 40.1 cm. Several days of cool weather followed. On September 11, 1979, hemp dogbane was at the pod set stage of growth, crown buds were pink and swollen and some leaves were yellowing. Air temperature was 27°C and corn was at the dent stage. Temperatures remained in the low to mid 30s°C for several days following. With both applications, the soil was moist, winds were 0-3.2 km hr^{-1} and skies were clear. The experiment was a randomized complete block design.

Hemp dogbane control with glyphosate in selective applicators

Glyphosate was applied on July 13, 1979, to hemp dogbane in soybeans at two locations near Ames, Iowa, using two designs of recirculating sprayers and two designs of rope wick applicators. Conditions at the time of applications were 31°C, partly cloudy, soil moist and a wind to 18 km hr^{-1} blowing across the direction of travel. On the McCay farm, soybeans were 30 to 46 cm tall and hemp dogbane was 91 to 107 cm tall. On the Swanson farm, soybeans were 46 to 61 cm tall and hemp dogbane was 91 to 107 cm tall. Both stands of dogbane were in the early flower stage of growth. A Porter box-type sprayer with 4 nozzles per row was used for some treatments. The sprayer was calibrated to deliver 2.4 liters min^{-1} row^{-1} and was operated at 124 kpa and 8 km hr^{-1}. A Spray Sickle broadcast sprayer was used for other treatments. It delivered 0.5 liters min^{-1} $nozzel^{-1}$ with 50.8 cm nozzle spacings and was operated at 0.7 kg cm^{-2} and 8 km hr^{-1}. Two designs of rope wick applicators were used. A 3.0 m wide applicator was constructed with a straight section of 5.1 cm diameter PVC pipe and 2 rows of wicks. Also, a commercial applicator manufactured by the Bobar Company was used. This applicator utilizes many ropes hung diagonally between two reservoir pipes. The experiments were designed as randomized complete blocks with 2 replications each. Plots were 2.1 to 3.0 m by about 61 or 91 m.

Percent soybean injury (yellowing) was rated on July 31, 1979. Plots were visually rated on July 9, 1980, to determine treatment effects on regrowth.

Photoperiod Response of Hemp Dogbane

Hemp dogbane seedlings, planted in April 1980, were transferred to clay pots (20 cm diameter by 21 cm deep) so that two plants established per pot. Plants were allowed to grow for two growing seasons under natural light in the greenhouse at 25°C. Dried top growth was cut at the soil surface each fall.

Pots with dormant root systems were transferred to growth chambers on January 14, 1982. Eight pots (replications) were placed in each of three chambers set for 10, 14, and 18 hr daylength photoperiods. Temperatures were maintained at 25°C. The irradiance was measured at the soil surface as 1500 $\mu E\ m^{-2}\ s^{-1}$ photosynthetic photon flux density with a Lambda Quantum sensor 50 cm below the light source. The light source consisted of full fluorescent (16 Sylvania cool white bulbs, F72T12 CW VHO) and incandescent (10 Sylvania 25 w bulbs rated at an average 235 lumen per bulb). The number of emerged shoots and plant height per pot were recorded every other day.

RESULTS AND DISCUSSION

Established hemp dogbane populations were not reduced significantly after 3 years of intensive tillage. Observing vegetative growth shortly after performing seedbed tillage operations may erroneously indicate suppression of hemp dogbane regenerative capacity. Initiation of hemp dogbane spring emergence occurred uniformly across tillages despite soil temperature differences. Perennial weed species established at a faster rate under reduced tillage systems, though populations increased under all tillage practices used.

Hemp dogbane exhibited seasonal trends in crown root nonstructural carbohydrate levels. Seedbed tillage did not significantly alter hemp dogbane carbohydrate or lipid levels. 2,4-D, dicamba, and glyphosate broadcast herbicide applications and glyphosate applied with selective equipment provided satisfactory hemp dogbane control. Photoperiod daylength significantly affected hemp dogbane winter dormancy break.

Established Hemp Dogbane Studies

Established hemp dogbane population response to soil tillage

Hemp dogbane populations tend to be nonuniform relative to annual and some perennial weeds with more deminutive rhizome or creeping root systems. Statistical data and a brief discussion on analysis of the absolute population

change over the base year population and covariance analysis are given in Appendix A. Covariance analysis was chosen to estimate least squared population means to compensate for rather large differences in base year populations.

Table 2 shows that all hemp dogbane populations increased by 1980 over the 1978 base year regardless of the tillage practice used. All populations decreased in 1981 over the 1980 tillage season but were still roughly equal or greater than the base year levels. No significant differences due to seedbed tillage treatments were found through covariance analysis. General trends, however, indicate that, by the end of the testing period, increased severity of tillage resulted in lower populations of hemp dogbane. These differences are quite small, ranging from 5.9 shoots/m^2 with continuous disk to 4.5 shoots/m^2 with fall moldboard plow treatments when comparing continuous tillage effects. The 1980 least square means show a noticeable increase in plants where continuous spring plowing was performed. This particular treatment suffered the largest decline in population from 1980 to 1981 however, and tended to compensate for this increase over the first two years. Root disruption likely released more buds for shoot production, but these shoot population levels could not be sustained.

Row cultivation treatments resulted in a general decrease in shoots/m^2 over all seedbed tillage treatments.

Table 2. Covariance least squared mean estimates for established hemp dogbane population seedbed tillage or row cultivation effects using 1978 base year populations as the covariate, Cumberland, Iowa, 1979-1981

Tillage[a]	1978 actual baseline counts	Least squared means 1980	1981
(1979-1981)	----------(Average plants/m^2)----------		
NNN	3.5	7.8	5.8
DDD	4.0	7.7	5.9
DDD(F)	3.7	8.4	5.9
CCC	4.3	6.6	5.4
CCC(F)	3.9	6.9	5.7
PPP	4.1	8.6	5.0
PPP(F)	5.5	6.1	4.5
CNN	3.4	7.1	4.6
CDD	6.5	5.6	5.1
CCN	3.1	-	4.5
CCD	4.3	-	5.5
PNN	4.9	7.2	5.9
PDD	2.6	7.4	5.0
PPN	4.8	-	6.2
PPD	5.3	-	5.6
PCC	5.2	7.6	4.9
PPC	4.4	-	4.6
Row cultivation[b]			
Yes	4.4	7.5	4.8
No	4.3	7.0	5.8
Overall mean	4.3	7.2	5.3

[a]Seedbed tillage in each of three years, performed in the spring except where marked F (fall tillage). N = no tillage, D = tandem disk, C = chisel plow, P = moldboard plow. Number of observations (n) = 8 reps except for 1980 CCC (n = 24) and PPP (n = 32).

[b]Number of observations (n) = 64.

Student t-tests revealed that cultivation effects were significant in 1981 but not in 1980. Table 3 shows that cultivation reduced the number of hemp dogbane shoots from 5.8 to 4.8 shoots/m^2 in 1981. Data for 1980 showed an increase in plants due to cultivation. Although this difference was not significant, trends indicate that some treatments did not disrupt hemp dogbane root systems sufficiently to avoid enhancing the propagation of this weed through bud release.

Seedbed tillage by row cultivation interactions were not significant by covariance analysis in 1980 or 1981. Table 3 for 1980 trends shows that, except for fall moldboard plow, populations increased when no tillage and disking were followed by a cultivation treatment. Cultivation of intact or relatively undisturbed hemp dogbane root systems merely released the crown buds from apical dominance, resulting in more shoots establishing than were removed. By 1981, fall moldboard plow was the only seedbed tillage where row cultivating versus not cultivating resulted in substantial hemp dogbane population increases. Fragmentation of roots through tillage increased the density of shoots per unit length of root in this case.

Again, there were no significant population differences due to seedbed tillage in either 1981 or 1980 by covariance analyses. Student t-tests of the least squared means did show some possible differences within these tillage treatments.

Table 3. Covariance least squared mean estimates for established hemp dogbane population seedbed tillage by row cultivation interaction effects using 1978 base year populations as the covariate, Cumberland, Iowa, 1979-1981

Tillage[a] (1979-1981)	1978 actual baseline counts		Least squared means			
			1980		1981	
	Cultivated	Non-cultivated	Cultivated	Non-cultivated	Cultivated	Non-cultivated
	(average plants/m^2)					
No tillage	3.6	3.4	8.0	7.6	5.5	6.1
DDD	3.9	4.2	8.0	7.4	5.6	6.2
DDD(F)	4.9	2.5	8.4	8.3	5.9	5.8
CCC	4.2	4.3	6.7	6.7	4.4	6.3
CCC(F)	3.7	4.2	6.3	7.5	5.2	6.2
PPP	4.2	4.0	8.5	8.7	4.3	5.6
PPP(F)	5.3	5.7	7.9	4.2	5.0	3.9
CNN	2.9	3.9	8.1	6.1	4.8	4.5
CDD	7.3	5.8	5.2	6.1	4.4	5.8
CCN	3.7	2.5	-	-	3.5	5.5
CCD	4.2	4.5	-	-	5.0	6.1
PNN	4.8	5.0	7.1	7.3	4.1	7.7
PDD	2.9	2.2	7.4	7.4	4.4	5.7
PPN	3.9	5.6	-	-	5.3	7.1
PPD	4.6	6.0	-	-	4.8	6.5
PCC	5.3	5.2	8.2	7.0	4.8	4.9
PPC	5.5	3.4	-	-	4.4	4.7
Overall mean	4.4	4.3	7.5	7.0	4.8	5.8

[a]Seedbed tillage in each of three years, performed in the spring, except where marked F (fall tillage). N = no tillage, D = tandem disk, C = chisel plow, P = moldboard plow. Number of observations (n) = 4 reps except for 1980 CCC (n = 12) and 1980 PPP (n = 16).

Treatments differing significantly at the 5% level in 1980 were spring chisel versus fall disking, spring chisel versus fall plow treatments, fall chisel versus spring plow treatments, fall disk versus fall plow treatments, and spring plow versus fall plow treatments. These differences generally all reflect a decreasing population trend with an increasing severity of tillage, except for the spring plow treatment which had an abnormally high increase in population over the 1978 base year. Student's t-test comparisons of least squared means for 1981 showed a significant difference at the 5% level only for spring disk versus fall plow treatments.

General overall indications are that the seedbed preparation tillage does not significantly affect established hemp dogbane populations. Post-planting row cultivation in addition to seedbed preparation can alter hemp dogbane populations, however. Trend analyses indicate a benefit due to more severe tillage in reducing hemp dogbane populations. This benefit is likely not a sufficiently large reduction in population due to increased severity of tillage to offset the added expense, increased soil erosion potential, and increased time and labor required for these tillage treatments. It is also important to note that none of the tillage treatments resulted in a substantial population decrease over that of the base year after 3 years of tillage. Continued tillage may indicate that the severe tillage could

reduce hemp dogbane populations, but this is purely conjecture.

These observations support the theory that the increase in hemp dogbane and other large rooted creeping perennial weeds may not be simply due to a general trend toward reduced or no-tillage farming. The whole realm of cultural practices must be examined. An increase in row crop production has reduced the number of acres that were rotated with hay crops or small grains. Hemp dogbane may compete better with open row crops than small grain and hay crops. Earlier harvest and repeated mowing of hay crops would tend to stress hemp dogbane root reserves. An additional factor is that of soil-applied herbicide use and early postemergence herbicide applications with row crop management practices. Except for early season suppression by thiocarbamate herbicides (Schultz and Burnside, 1979a), neither of these herbicide application methods effectively control established hemp dogbane. Late season postemergence herbicide applications and the possible use of small grain and hay crops where they can be utilized must be considered as an integral part of any hemp dogbane control program.

Observations on established hemp dogbane vegetative growth and soil tillage

General observations were made on the growth and effects of tillage on hemp dogbane during all three years of study.

Observations were taken on shoot emergence, plant growth, regrowth, flowering, pod set, and maturation as well as any other observations of interest.

Spring moldboard plowed plots exhibited a 2-week delayed emergence of hemp dogbane shoots relative to the other tillage treatments in 1980 and 1981. Fall moldboard plowed plots in 1981 had a few buds emerging earlier at the same time as other tillage treatments, but only from disrupted crowns and lateral roots that were near the soil surface. Hemp dogbane emergence occurred during a prolonged period regardless of tillage practices. There was a tendency, however, for more shoots to emerge earlier with lesser tillage treatments. (See soil temperature relationships and hemp dogbane emergence following this section.) The 1979 seedbed tillage treatments were performed after hemp dogbane had already emerged but before emergence in 1980 and 1981. There appeared to be a longer detrimental effect of more severe tillage on hemp dogbane in 1979 compared to 1980 and 1981, perhaps due to greater depletion of carbohydrate reserves. Moldboard plow treatments tended to result in shoot emergence from disrupted crowns and lateral roots within the plow layer first, with subsequent emergence of shoots from below the plow layer zone. Shoots emerging from below the plow layer zone were etiolated and slender.

Herbicide treatments applied preemergent to the crop

resulted in top growth burn of emerged hemp dogbane shoots. This top growth burn appeared more severe where lesser tillage treatments were performed due to more advanced vegetative growth at the time of spray application. Reduced tillage plots had higher absolute numbers of emerged shoots at all stages up to 46 cm in height, even though more severe tillage plots had a higher percentage of emerged vegetation under 15 cm. About 70-90% of the emerged vegetation showed solvent or triazine burn a week after application, but only 10-20% suffered complete shoot kill after one month. Shoots less than 15 cm in height were usually desiccated with new shoots arising from adjacent buds.

Regrowth or new shoots sprouting from underground root systems occurred throughout much of the growing season. New shoot emergence occurred in all tillage treatments, but was most notable where moldboard plowed or row cultivation treatments were performed. Midseason regrowth was noted by Schultz and Burnside (1979b) in response to defoliation by hail and insects. Row cultivation resulted in similar bud release in this study. Regrowth where plants were broken off or where cultivation removed top growth was less vigorous with slender stems emerging from rather heavy plant crowns.

Maturation generally resulted in complete shoot senescence with vegetative decay proceeding down the stem but stopping at or just below the soil surface. Crowns and

lateral roots below the soil surface remained healthy in appearance with latex present. There appeared to be no definite morphological boundary where decay stopped, preserving crown reserves for next season's growth. Some shoots were observed to decay farther down in the soil profile with death of partial crown root areas.

A sporadic wilting and death of individual shoots was noticed in all three years. This appeared to be a vascular wilt which began as discolored leaves with dark streaking through petiole vascular tissue which eventually entered the stem and progressed down to the soil surface. Sometimes, this appeared to travel along connecting lateral roots with a few plants in an area wilting and showing premature senescence. Senescence was as much as 2-3 months advanced of that of normal plants. These symptoms were never observed on more than 1% of the population and a positive identification of the causal organism could not be obtained. Fairly heavy feeding by the dogbane beetle (Chrysochus auratus) was observed in 1981. Less than 1% of the plant population showed dogbane feeding symptoms and feeding was not likely detrimental to the plant population as a whole. Insect feeding on hemp dogbane has been reported elsewhere (Roeth, 1977; Schultz and Burnside, 1978).

Soil temperature relationships and hemp dogbane emergence

Soil temperatures during the study period warmed more slowly and diurnal fluctuations, especially daily maximums, dampened as tillage decreased and less crop residue was buried. Similar effects have been reported due to mulch (Moody et al., 1963; Burrows and Larson, 1962). Lesser tillage tended to conserve moisture as has been reported (Jones et al., 1969; Blevins et al., 1971). Soil temperature variations by depth followed amplitude reduction and phase retardation as discussed in Stoller and Wax (1973), Priestley (1959), and Elford and Shaw (1960). The mean for daily average and maximum soil temperatures for part of April and all of May 1980 and 1981 are presented in Appendix B.

Hemp dogbane emergence in moldboard plow treatments was delayed 15 days in both 1980 and 1981 compared to less severe tillage treatments. Initial emergence in disk or chisel plow treatments was identical to that in no tillage, but the rate of emergence was lower as the severity of tillage increased. No effects on emergence due to row cultivation in the previous season were detected.

Table 4 shows soil temperatures in the five-day period preceding initial hemp dogbane emergence. The highest daily maximum soil temperature preceding emergence in tillage treatments other than moldboard plow ranged from 13.6°C with 1980 no tillage to 17.5°C in 1981 chisel plow treatments. Hemp

Table 4. Highest daily maximum soil temperature by tillage and depth during the five-day period preceding hemp dogbane emergence, Cumberland, Iowa, 1980-1981

Sensor depth	Seedbed tillage	Highest daily maximum soil temperature	
		1980[a]	1981[b]
(cm)		--------(^{o}C)--------	
10-16	No tillage	13.6	15.3
	Tandem disk	16.3	16.7
	Chisel plow	17.2	17.5
	Moldboard plow	19.5	25.8
30-48	No tillage	12.0	12.0
	Moldboard plow	14.4	17.2

[a]Values for emergence on 05/13/80 for moldboard plow, all others on 04/28/80.

[b]Values for emergence on 05/03/81 for moldboard plow, all others on 04/18/81.

dogbane emergence has been observed at soil temperatures of 17-19^{o}C around lateral roots (Schultz and Burnside, 1979b) and was delayed in cooler soils under sod. No delay in emergence was apparent in cooler no-tillage soils in this study.

Seedbed tillage was more limiting than soil temperatures in moldboard plow treatments. Soil temperatures where moldboard plowed probably did not relate biologically to hemp dogbane emergence. Similar effects on hemp dogbane emergence were noted where soybean cropping tillage was performed

(Schultz and Burnside, 1979b).

Hemp dogbane height, ground cover, flowering, pod set, and maturation as affected by soil tillage

General field observations indicate that morphological development and plant vigor were adversely affected immediately after seedbed tillage or row cultivation. These differences lessen as the season progressed, and are often not apparent when plants fully mature. Therefore, observations taken at certain points in time throughout the season may indicate that tillage greatly affects hemp dogbane population and potentially lowers perennial regenerative capacity. This was not apparent by counts taken of plant populations or when viewing plants at maturation, however.

Row cultivation treatments with the rolling cultivator successfully removed most hemp dogbane shoots between crop rows. Dogbane shoots within crop rows were not visually damaged and generally developed much like plants in non-cultivated areas. Spot checks before the 1980 cultivation was performed did not indicate a difference in plant height, ground cover, or flowering due to cultivation in 1979, so data were taken only on the whole plot seedbed tillage practices.

Spot checks before the 1981 row cultivation was performed showed a few differences due to cultivation in 1979 and 1980. Data were therefore taken on a split-plot basis.

Notes were taken on a whole-plot basis in July 1981 to document the change in ground cover, height, and flowering differences due to seedbed tillage with time. Percent ground cover is a visual estimate of biomass corresponding to plant height, health, and vigor. Taking these observations and measurements on a split-plot basis shortly after the cultivation was performed would obviously show some differences due to cultivation. Cultivated plot interrow hemp dogbane generally did not flower and rarely set pods before senescence occurred.

A summation of statistical data for 1980 and 1981 seedbed tillage and row cultivation is presented in Appendix A, Tables 20 and 21. Table 5 shows hemp dogbane ground cover, height, flowering, and maturation as affected by soil tillage with Duncan's multiple range comparisons at the 5% level. Continuous spring and fall moldboard plow treatment heights were significantly lower than no-tillage heights in 1980. Flowering in continuous spring and fall moldboard plow treatments was significantly delayed compared to all other tillages. Spring and fall moldboard plow ground cover was significantly less than spring chisel, spring and fall disk, and no tillage treatments. Only fall moldboard plow ground cover was significantly less than fall chisel treatments. Several trends for continuous seedbed tillage treatments, when apparent, were for increasing severity of tillage to decrease

Table 5. Average hemp dogbane heights, percent ground cover, flowering, and maturation by tillage practice, Cumberland, Iowa, 1980-1981[a]

Tillage 1979-1981	1981 split plot				1981 split plot
	Ground cover (%) 6-20-81	Flowering (%) 6-20-81	Height (cm) 6-20-81	Maturation (%) 10-5-81	Ground cover (%) 7-8-81
NNN	64.6a	22.5abcd	93.7a	86.6a	72.5ab
DDDS	39.5abcd	9.4cd	81.9a	73.7abc	70.0ab
DDDF	41.3abcd	4.0cd	88.0a	62.5abc	60.0ab
CCCS	32.5abcd	6.7 cd	86.1a	67.5abc	76.2ab
CCCF	20.0bcd	18.5bcd	80.8a	60.6abc	76.2ab
PPPS	12.5d	3.7cd	45.7c	33.1d	41.2b
PPPF	13.8cd	6.3d	53.5bc	47.5cd	42.5b
CNN	42.5abcd	24.4abc	70.5ab	50.6cd	65.0ab
CDD	46.6abcd	12.3cd	93.3a	70.6abc	83.8a
CCN	45.9abcd	16.3cd	87.6a	55.0bcd	66.2ab
CCD	37.0abcd	10.2cd	89.9a	63.7abc	75.0ab
PNN	48.1abc	41.9a	93.3a	75.0abc	94.0a
PDD	27.6bcd	12.0cd	81.9a	61.3abc	58.8ab
PPN	64.6ab	38.7ab	94.9a	80.6ab	90.5a
PPD	27.6bcd	25.9abc	86.5a	62.5abc	80.0ab
PCC	22.6bcd	8.1cd	88.4a	53.7bcd	77.5ab
PPC	21.4bcd	9.4cd	78.5a	63.7abc	41.2b
Cultivation					
Yes	26.0b	3.2b	83.0a	58.5b	
No	44.3a	27.9a	81.1a	67.2a	

[a]Means followed by the same letter do not differ significantly at the 5% level according to the Duncan's multiple range test.

1981 whole plot			1980 whole plot		
Flowering (%) 7-8-81	Height (cm) 7-8-81	Pod set (%) 8-5-81	Ground cover (%) 7-9-81	Flowering (%) 6-24-80	Height (cm) 7-9-81
86.2a	120.4ab	87.5a	76.2a	65.0ab	129.5a
81.2a	121.9ab	87.5a	65.0a	74.8a	114.3ab
71.2a	114.3ab	100.0a	66.2a	73.8ab	114.3ab
70.0a	125.7a	71.9a	60.4a	54.2ab	97.8ab
67.5a	125.7a	87.5a	57.8ab	70.0ab	99.1ab
31.2b	106.7ab	71.9a	34.4bc	6.2c	84.8b
43.8b	109.0ab	71.9a	17.5c	7.5c	80.0b
65.0a	102.9ab	75.0a	62.5a	51.2ab	95.2ab
80.0a	133.4a	90.6a	80.0a	62.5ab	118.1ab
81.2a	124.2a	75.0a	-	-	-
82.5a	129.5a	75.0a	-	-	-
86.2a	125.7a	75.0a	71.2a	52.5ab	118.1ab
80.0a	121.9ab	87.5a	48.8ab	47.5b	106.7ab
87.5a	121.9ab	87.5a	-	-	-
72.5a	129.5a	79.4a	-	-	-
70.0a	121.9ab	87.5a	60.0a	50.0ab	106.7ab
35.0b	86.1b	100.0a	-	-	-

plant height, percent ground cover, and to delay flowering. There was a general lessening of differences in morphological development due to tillage with time. No differences in maturation, measured as leaf loss and stem dry down, were apparent in the fall of 1980.

Split-plot analysis data for 1981 for flowering, ground cover, and height were taken on June 20th. Whole-plot data were taken 18 days later on July 8th. Percent flowering in June did not differ due to seedbed tillage. Floral initiation was just beginning at this time. Trends did show a general delay in flowering as the severity of seedbed tillage increased. By July, spring and fall moldboard plow flowering was delayed significantly compared to all other continuous tillage treatments. Statistically, absolute floral initiation appeared more dependent on environmental factors such as day-length than on seedbed tillage. The rate and degree of flowering were affected by seedbed tillage, however, as seen in July data.

Hemp dogbane shoot height was significantly reduced with spring and fall moldboard plow treatments relative to all other continuous seedbed tillages in June, but these differences were not apparent in July. Percent ground cover was significantly lower with spring and fall moldboard plow and fall chisel plow than with no tillage treatments, but these differences were not apparent in July either.

Maturation, measured as pod set, was not altered by seedbed tillage as noted on August 5, 1981 when pod set in most plants was well under way. Maturation measured as leaf loss and browning was significantly delayed by spring moldboard plow when compared to less severe continuous seedbed tillage treatments on September 5, 1981. Fall plow maturation was delayed compared to no tillage treatments. No differences in maturation due to seedbed tillage could be detected 21 days later, however.

Row cultivation versus no row cultivation during 1979 and 1980 decreased percent ground cover and flowering but not height, as measured on June 20, 1981. Maturation was delayed by row cultivation in all 3 years as measured on September 5, 1981. Seedbed tillage and row cultivation interactions were not significant. Pod set throughout the population appeared to be indeterminant. Pods generally aborted in lower plant areas, particularly where plant stands were dense. This generally occurred after pods obtained a 1-2 cm length. By November 1981, plants had generally aborted virtually all pods except for a few at the very top. Schultz and Burnside (1979b) noted poor pod set for hemp dogbane in field situations as well.

Leaf drop generally occurred in a similar fashion with lower plant areas turning brown and losing leaves earlier than the upper portions. Relatively young plants that had

not reached reproductive stages of growth generally would senesce with leaf browning and stem drying during the same time period of plants more morphologically advanced.

Tillage did affect hemp dogbane shoot height, percent ground cover, and flowering. These differences exist dependent on the time interval since tillage was performed. Shoot counts were not significantly altered, the majority of the lateral root system was unaffected, and carbohydrate reserves were not depleted in response to tillage, however, (See sections on population, observations on lateral root development, and carbohydrate levels in response to soil tillage.) Inferences made that more severe tillage controls hemp dogbane from viewing plant development are therefore often misleading.

Observations on hemp dogbane crown and lateral root development as affected by soil tillage

Hemp dogbane root systems were excavated in each seedbed tillage treatment in 1980 and 1981. The general form and development of crown and lateral root systems was examined. Hemp dogbane plants form a large creeping root system with relatively low lateral densities. On the average, a transect would intercept 2 or less roots per 30 cm in any given plane between crowns. For the purpose of this study, crown roots will be defined as the portion of vertical root descending from the soil surface which enlarges beyond normal

lateral and vertical root diameters. Schultz and Burnside (1979b) defined crown roots as the vertical root portion above the lateral roots. This refinement was necessary due to the depth of hemp dogbane root development observed.

Crown roots originated throughout the depth examined in this study, the deepest originating at 110 cm. Tillage treatments even as severe as moldboard plow or chisel plow would disrupt only the surface of hemp dogbane creeping root systems. A moldboard plow treatment cuts off crown roots and disrupts lateral roots within the plow layer zone. Chisel plow treatments tend to slice through several lateral roots and disrupt a few crown root systems. Disk treatments result in breaking the tops of the crown root, if any damage at all is inflicted. No-tillage treatments leave the root system intact.

A multiple crown effect was apparent in the no tillage, chisel, and disk treatments. It appears that a crown, after more than one season, decays to where new crowns have developed from crown buds off the same lower crown area. This can result in a crown set that covers approximately 90 mm, but still any given crown was at most 26 mm in diameter. These multiple crowns generally divide from the main vertical root within 20 cm of the soil surface, but were observed dividing as far down as 40 cm. Frazier (1944) found adventitious buds throughout lateral roots but never on primary or vertical roots. His observations were made on one-year-old plants

which would not have evolved into multiple crown systems yet.

An analysis of variance summation of crown and lateral root data is presented in Appendix A, Table 22. Table 6 shows the maximum and average diameter of crown and lateral roots, depth from which vertical roots began thickening into crown root systems, and the general distribution of laterals. Lateral and vertical roots below the crown root generally were 8-10 mm in diameter and did not appear to enlarge beyond this point even when left undisturbed. Crown roots, however, continued to thicken when left undisturbed. Growth rings were apparent through cross sections of older crown roots. Tillage treatments, other than moldboard plowed, tended to leave crown roots intact and resulted in an average crown diameter of 18 mm. Average moldboard plowed crown root diameters were only 11 mm, reflecting the annual disruption of the crown.

Findings by Evetts and Burnside (1974) that common milkweed roots tended to be enlarged due to tillage do not hold for hemp dogbane in this study. Their observations on milkweed could have been due to milkweed's inability to compete with smooth brome pastures, rather than the fact that no tillage was performed in the brome pasture.

Crowns that were moldboard plowed annually had limited cambial growth within one year's time and only had 1-2 rings of xylem tissue with little inner soft pith. The less severe

Table 6. Hemp dogbane crown and lateral root maximum and average diameters and average distribution within a 150 cm depth following 3 years of tillage, Cumberland, Iowa, 1981

Tillage practice	Crown roots[a]			Lateral roots[a]		
	Maximum diameter observed (mm)	Average diameter (mm)	Average depth[b] (mm)	Maximum diameter observed (mm)	Average diameter (mm)	Average depth (cm)
No tillage	26	17.5a	27.5a	17	10.5a	33.0a
Tandem disk	30	17.5a	25.0a	15	8.5a	30.2a
Chisel plow	30	18.5a	30.0a	15	10.5a	33.0a
Moldboard plow	20	10.8b	26.8a	15	8.5a	40.5a

[a]Means within the same column followed by the same letter do not differ significantly at the 5% level according to Duncan's multiple range tests.

[b]Average depth at which vertical roots began to enlarge into crowns.

tillage treatments resulted in undisturbed crowns that, over the years, generally had 2-3 rings of xylem tissue with an inner pith. The average depth of lateral distribution was driven downward by the more severe moldboard plow treatments. Disrupted crown roots that were capable of producing shoots did not produce laterals within the plow layer zone. Lateral formation appears to be a slow, energy intensive process and generally developed below the plow layer zone. Lesser tillages, especially no-till and disking, had lateral distribution generally from 5 mm on downward throughout the depth of the soil profile examined. Chisel plow treatments had a rather marked proliferation of laterals from some of the heavier crowns. This reflects the effective disruption of lateral, but poor disruption of crown roots, by chisel plowing. Heavy crowns had adequate carbohydrate reserve to produce more laterals, as well as new vegetative growth in chisel plowed treatments.

Crowns that were upturned by moldboard plow treatments usually produced shoots, only once were observed to produce lateral roots, and rarely produced root hairs as was noted for field bindweed (Swan and Chancellor, 1976). This indicates conservation of crown carbohydrate reserves to produce new shoots to maintain carbohydrate levels. Crowns were able to sustain growth throughout the season and did not degenerate after shoot production as was observed with johnsongrass

rhizomes (McWhorter, 1961). Spread of hemp dogbane by creeping roots in moldboard plow areas would have to come from laterals below the plow layer zone.

Young ascending vertical roots generally were etiolated and often elongate. These were present in all tillage plots, but were much more prevalent in moldboard plow treatments. Some moldboard plowed plots had relatively heavy crowns that ended at the plow layer subsurface interface, and appeared to have repeatedly produced new shoots through the plow layer with buds and general appearances resembling crowns right at the soil surface.

Adventitious buds were not common throughout the depths observed. Some laterals within a few centimeters of the soil surface did produce buds which occurred at approximate 40-cm intervals. The longest laterals traced were two 2-m lengths. Hitchcock and Clothier (1898) traced a hemp dogbane lateral root 8.8 m, but did not find any regularity of root-borne buds. The heavy deep penetrating roots of hemp dogbane relative to the corn crop present indicate that hemp dogbane should compete effectively in dry conditions, as was noted with field bindweed (Bakke, 1939).

Perennial Weed Establishment and Soil Tillage

An ongoing tillage study initiated in 1977 gave an opportunity to monitor perennial weed population response to

seedbed preparation tillage. Populations in 1976 consisted of scattered infestations of perennial species, none of which required special treatment consideration. After five years of various tillage practices, many perennial weeds became more prominent, increasing in all tillage methods, but at a faster rate with less severe tillages. Cropping rotation influenced some populations as well.

Data taken in 1980 reflected four years under a given tillage practice, while 1981 data reflected 5 years of tillage. An analysis of variance summation is presented in Appendix A, Table 23. Hemp dogbane and American germander were the only perennial species that had increased to levels requiring special control measures. None of the tillage by crop rotation interactions were significant, except for field bindweed in 1981. Corn in rotation had higher field bindweed populations than continuous corn or soybeans in rotation, but the tillage interaction means did not appear biologically significant. Table 7 shows that, during 1980 and 1981, common milkweed had significantly higher populations in no tillage and till-plant as opposed to chisel plow and moldboard plow systems. Yellow nutsedge populations were significantly higher in reduced tillage systems in 1981, but the overall infestation was not severe in any tillage. Total perennial weed populations were significantly higher with no tillage in 1980 only.

Table 7. Perennial weed populations after four and five years of various seedbed tillage practices, Nashua, Iowa, 1977-1981

Tillage	Weed species[a]						
	Hemp dogbane	American germander	Field bindweed	Yellow nutsedge	Common milkweed	Canada thistle	Total
	(Average plants/ha)						
June 19, 1980							
No tillage	4631.4a	3164.0a	240.7a	1071.9a	146.2a	11.5a	9202.7a
Till-plant[b]	2671.1a	4081.2a	272.3a	323.9a	146.2a	22.9a	7517.5ab
Chisel plow	2315.7a	1516.1a	240.7a	149.0a	37.3ab	8.6a	4207.4b
Moldboard plow	2201.1a	2003.3a	312.4a	91.7a	17.2b	0.0a	4625.7b
June 25, 1981							
No tillage	2894.6a	1447.3a	343.9a	587.5a	68.8a	40.1a	5382.3a
Till-plant[b]	1415.8a	1498.9a	455.7a	186.3ab	97.4a	252.2a	3906.3a
Chisel plow	1183.6a	163.4a	323.9a	20.1b	2.9b	0.0a	1693.8a
Moldboard plow	2192.5a	2759.9a	515.9a	17.2b	2.9b	0.0a	5488.3a

[a]Means followed by the same letter within the same species and year do not differ significantly at the 5% level according to Duncan's multiple range tests.

[b]Buffalo till-plant system.

Table 8 shows that by 1980, although not significant statistically, crop rotation had reduced hemp dogbane populations with glyphosate applied through a rope-wick applicator in soybeans in 1979. Hemp dogbane in the other corn-soybean rotation was treated with glyphosate similarly in 1980, reducing hemp dogbane populations so corn-soybean rotation differences were no longer apparent by 1981. This helps account for the loss in significant effects of tillage on total perennial weed populations in 1981 compared to 1980 as well. Hemp dogbane populations in both years and both crop rotation and tillage treatments indicate that reduced tillage systems may have resulted in more effective control of hemp dogbane with glyphosate. This may be the result of more advanced early season growth of hemp dogbane under reduced tillage, giving better crop-weed height differentials and more desirable weed maturity at the time of glyphosate application. The advanced growth of hemp dogbane in relation to soil tillage was discussed earlier in the established hemp dogbane development in response to soil tillage section.

Field bindweed populations in both 1980 and 1981 were significantly lower in continuous corn versus corn-soybean rotations. American germander trends show populations were considerably lower in continuous corn as well. Atrazine use in continuous corn may be suppressing these weeds. Weed-crop height differentials did not allow glyphosate applica-

Table 8. Perennial weed populations after four and five years of various crop rotation sequences, Nashua, Iowa, 1977-1981

Crop rotation[b]		Weed species[a]						
		Hemp dogbane	American germander	Field bindweed	Yellow nutsedge	Common milkweed	Canada thistle	Total
(Odd # year)	(Even # year)	(Average plants/ha)						
June 19, 1980								
Corn	Corn	3336.0a	167.7a	12.9b	900.6a	60.2a	30.1a	4507.5a
Corn	Soybeans	4193.6a	4389.2a	429.9a	199.9a	90.3a	2.1a	9305.1a
Soybeans	Corn	1334.8a	3516.6a	356.8a	126.8a	62.3a	0.0a	5397.4a
June 25, 1981								
Corn	Corn	2822.3a	109.6a	0.0b	406.3a	36.5a	12.9a	3387.6a
Corn	Soybeans	1790.5a	2882.5a	649.1a	169.8a	43.0a	169.8a	5704.7a
Soybeans	Corn	1152.1a	1410.1a	580.4ab	32.2a	49.4a	36.5a	3260.8a

[a]Means followed by the same letter within the same species and year do not differ significantly at the 5% level according to Duncan's multiple range tests.

[b]Corn-soybean rotations were duplicated such that a given year had both the corn and soybean phase of crop rotation planted.

tion through rope-wick applicators to either of these species in soybeans. Trends indicate that yellow nutsedge populations were lower under corn-soybean rotations than under continuous corn. This may be due in part to soybean crop competitiveness against yellow nutsedge (Simkins and Doll, 1981).

Trends indicate that perennial weed infestations studied here, with the exception of field bindweed, intensified at a faster rate under reduced tillage. Absolute weed populations increased under all tillages, however. Field bindweed populations were relatively uniform throughout all tillages, but always highest under moldboard plow treatments. Cropping systems must be scrutinized considering changes in all cultural practices when assessing perennial weed population shifts.

Hemp Dogbane Nonstructural Carbohydrate Levels with Seasonal and Root Depth Effects, Qualitative Carbohydrate Analysis, and Seasonal Lipid Levels

Hemp dogbane total nonstructural carbohydrate (TNC) levels followed expected seasonal trends. Starch was the major carbohydrate storage form and ethanol soluble carbohydrates were mostly sucrose. Carbohydrate levels varied with depth of crown roots. Seasonal effects for lipids were erratic.

Seasonal carbohydrate levels

Hemp dogbane crown root storage TNC levels begin to fall with vegetative growth in the spring (Figures 1 and 2). Table 9 shows hemp dogbane developmental stages for 1980 and 1981 sampling dates. Carbohydrate levels reached seasonal lows during flowering. Carbohydrate levels began to build from that point on until the plants entered dormancy in the fall. This reflects net photosynthate-root storage-seasonal energy demand relationships.

Analysis of variance data and contrast mean square data are summarized in Appendix A, Table 24. Stepwise orthogonal contrasts reveal that significantly lower levels of reducing carbohydrates occurred when total overall carbohydrate levels were high, and reducing levels were significantly higher when total carbohydrate levels were low during both 1980 and 1981. TNC and starch carbohydrate levels were significantly lower during early bud in 1980 and midflower stages of development in 1981. TNC and starch carbohydrate levels were significantly at their highest during spring and fall dormant stages in both 1980 and 1981. Nonreducing and total ethanol soluble sugar levels did not show any significant differences over months by contrast comparisons. General trends were like those of starch and TNC levels mentioned previously, however.

The major carbohydrate present in hemp dogbane crown

Figure 1. Seasonal hemp dogbane crown root nonstructural carbohydrate levels, Cumberland, Iowa, 1980

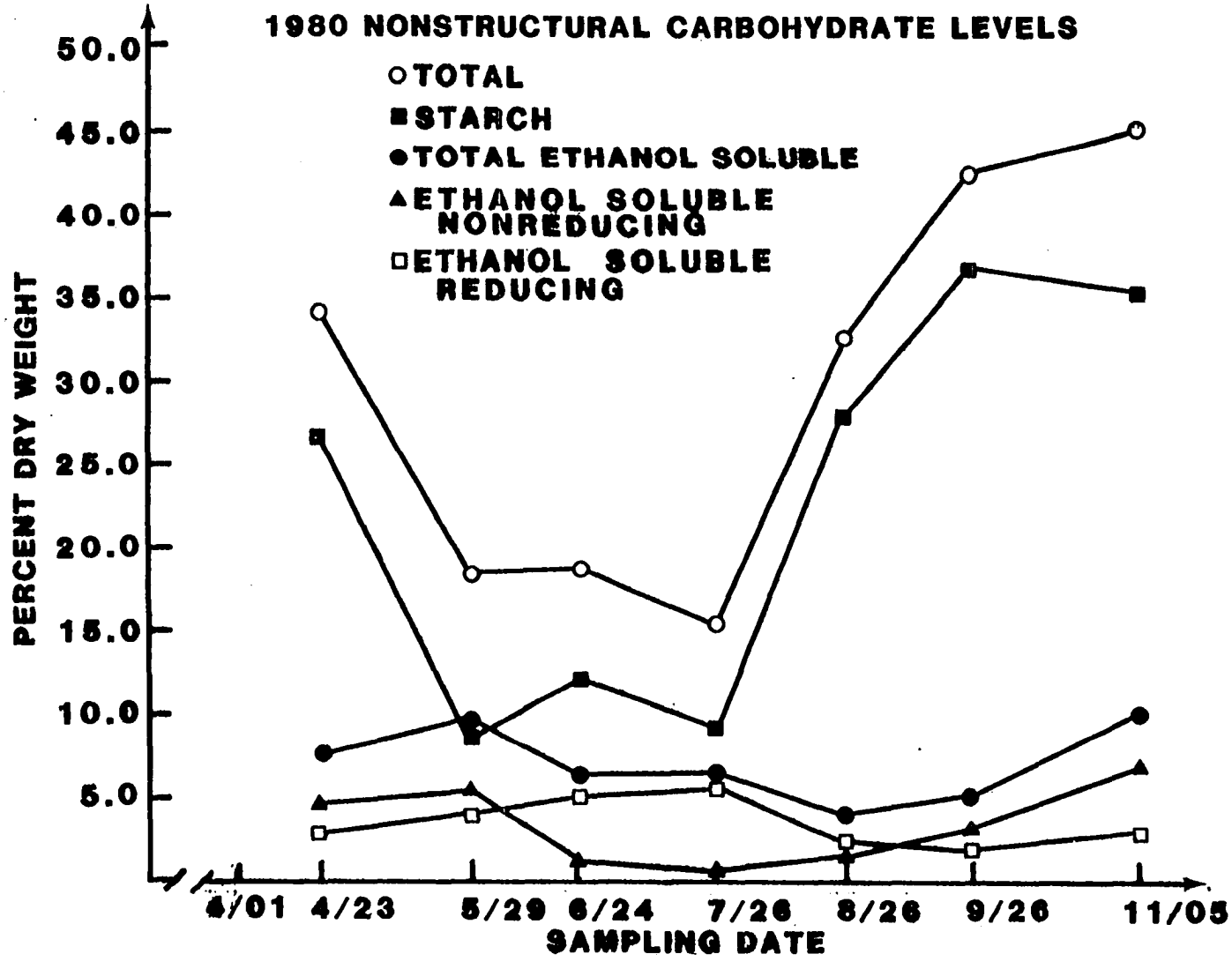
1980 NONSTRUCTURAL CARBOHYDRATE LEVELS
TOTAL
STARCH
TOTAL ETHANOL SOLUBLE
ETHANOL SOLUBLE NONREDUCING
ETHANOL SOLUBLE REDUCING
PERCENT DRY WEIGHT
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
4/01
4/23
5/29
6/24
7/26
8/26
9/26
11/05
SAMPLING DATE

Figure 2. Seasonal hemp dogbane crown root nonstructural carbohydrate levels, Cumberland, Iowa, 1981

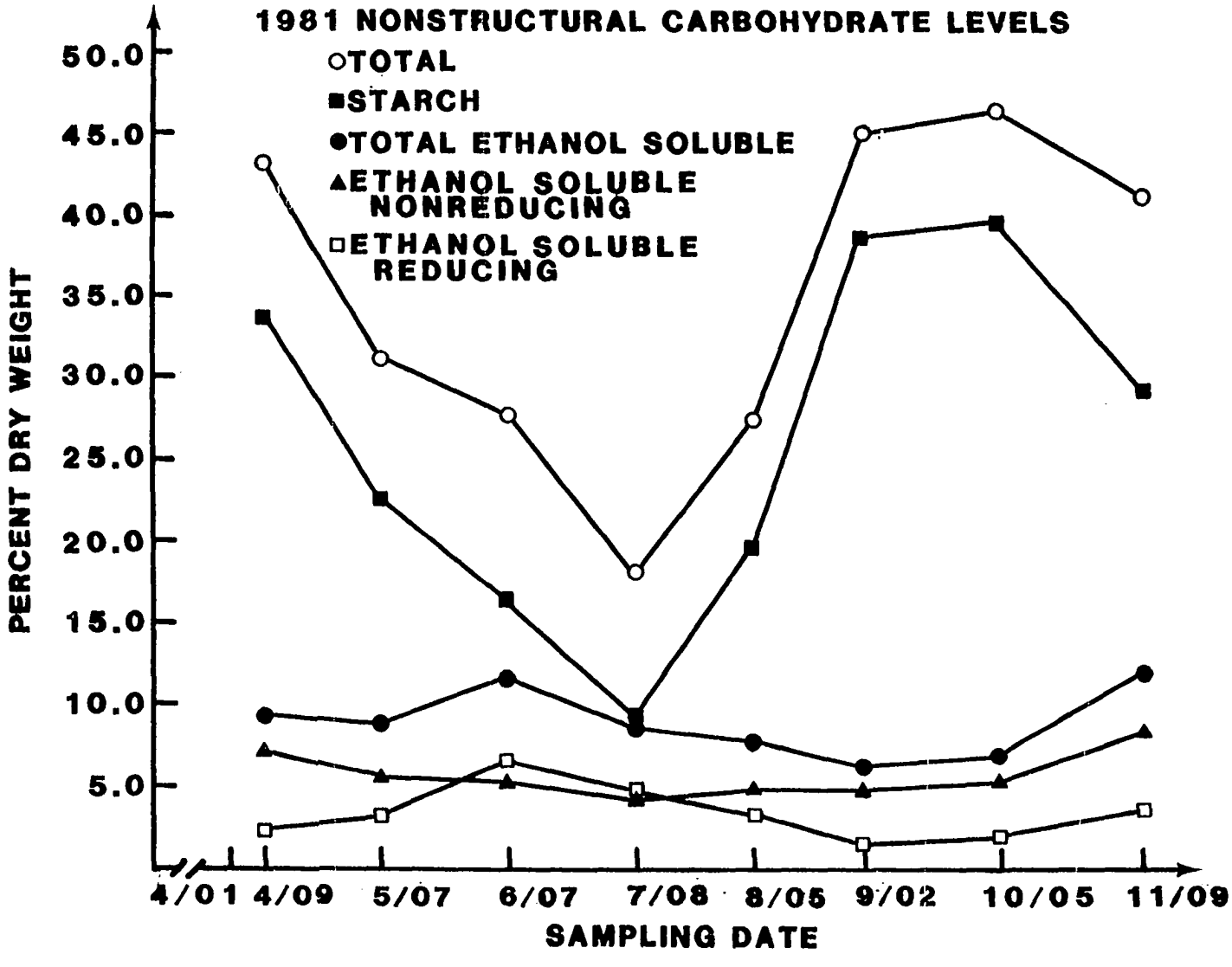
1981 NONSTRUCTURAL CARBOHYDRATE LEVELS
○TOTAL
■STARCH
●TOTAL ETHANOL SOLUBLE
▲ETHANOL SOLUBLE NONREDUCING
□ETHANOL SOLUBLE REDUCING
PERCENT DRY WEIGHT
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
4/01 4/09 5/07 6/07 7/08 8/05 9/02 10/05 11/09
SAMPLING DATE

Table 9. Hemp dogbane stage of growth relative to seasonal carbohydrate and lipid sampling dates, Cumberland, Iowa, 1980-1981.

Sampling date		
Year	Month/day	Hemp dogbane stage of growth
1980	04/23	Dormant
	05/29	50-70% at early bud, shoots approx. 76.2 cm in height
	06/24	50-70% at midflower
	07/26	10% at late flower, 90% at early pod, pods 2.5-5.0 cm long
	08/26	100% pod set, pods 10-14 cm long
	09/26	100% late pod, 10% defoliation
	11/05	Mature (dried down)
1981	04/09	Dormant
	05.07	Shoots approx. 25.4 cm in height
	06/07	80-100% at early bud, shoots approx. 68.6 cm in height
	07/08	75-95% at midflower
	08/05	Late flower-early pod set, pods 0.3-1.3 cm long
	09/02	10% at midpod, 90% at late pod, pods 9-12 cm long
	10/05	80-90% mature (leaf loss, stems drying)
	11/09	Mature (dried down)

roots was starch. Starch levels were as high as 39.6% dry weight in 1981 during dormancy. The lowest starch level was 9.2% in 1980 during flowering. Total ethanol soluble sugar exceeded starch levels only on the May 29, 1980 sampling date. Ethanol soluble reducing sugar levels were negatively correlated with starch levels with r values of -0.79 and -0.76 in 1980 and 1981, respectively. Nonreducing and total ethanol soluble carbohydrate correlations, although negative, were not highly significant.

Seasonal reducing sugar levels tended to increase, while nonreducing sugars decreased when starch and TNS levels were at seasonal lows. This occurred when the energy demand on crown root reserves was at a maximum as plants began flowering. Sucrose was likely the carbohydrate form being translocated out of crown roots as rapidly as it was produced, giving low nonreducing sugar values. Increased reducing sugar levels may reflect immobile starch conversion to maltose and glucose which accumulated temporarily awaiting conversion to sucrose for translocation.

Starch levels dropped in November each year from seasonal highs which occurred near the beginning of September. The starch level decline from seasonal highs was statistically significant only for 1981. A corresponding rise in ethanol soluble reducing and nonreducing sugars occurred simultaneously. Similar results with field bindweed have been observed

(Barr, 1940) and termed "hardening off" as fall temperatures lowered.

Seasonal lipid levels

Hemp dogbane has considerable latex throughout vegetative parts, crown, and lateral roots. Lipid levels show that residue lipids (ethanol insoluble) never exceeded ethanol soluble lipids (Figures 3 and 4). Lipid levels generally increased during periods of high metabolic activity from early bud to late flower, and lowered as plants entered dormant stages. Ethanol soluble lipid levels dropped after early bud to flower stages of growth and were significantly lower as plants began to mature. This corresponded to a lack of visible latex in aerial plant parts before advanced stages of leaf browning. Both 1980 and 1981 ethanol soluble lipid levels increased as plants entered full dormancy in the last month of sampling. Residue lipids followed trends similar to ethanol soluble lipids in 1980, except levels fluctuated less. Residue lipid levels did not differ significantly by months during 1981.

Significant changes in total lipids are reflected in those of ethanol soluble lipids, Hemp dogbane total lipid level in 1980 and 1981 increased as plants entered dormancy. Only lipid levels in 1981 increased significantly.

Hemp dogbane crown and lateral roots seem quite cold

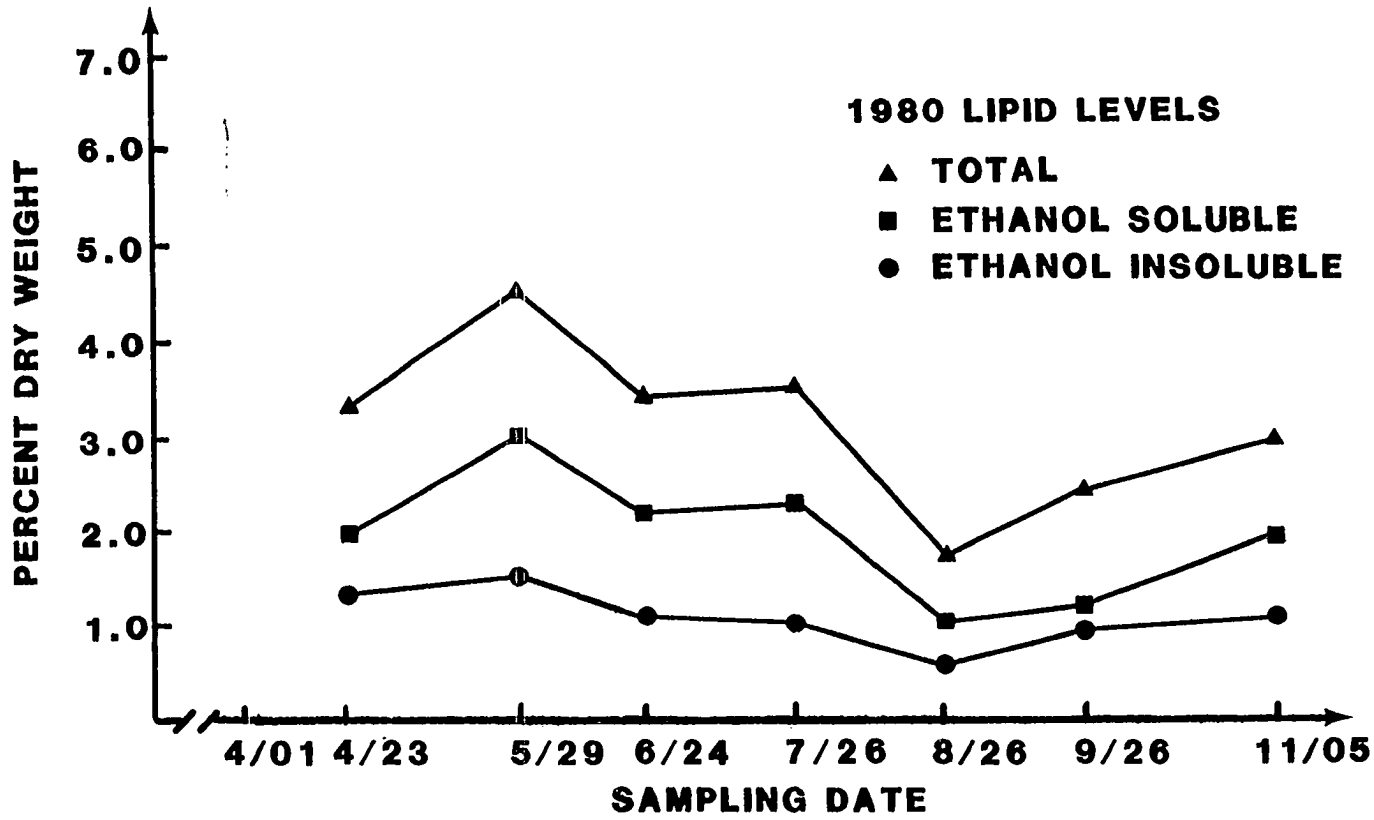

Figure 3. Seasonal hemp dogbane crown root lipid levels, Cumberland, Iowa, 1980

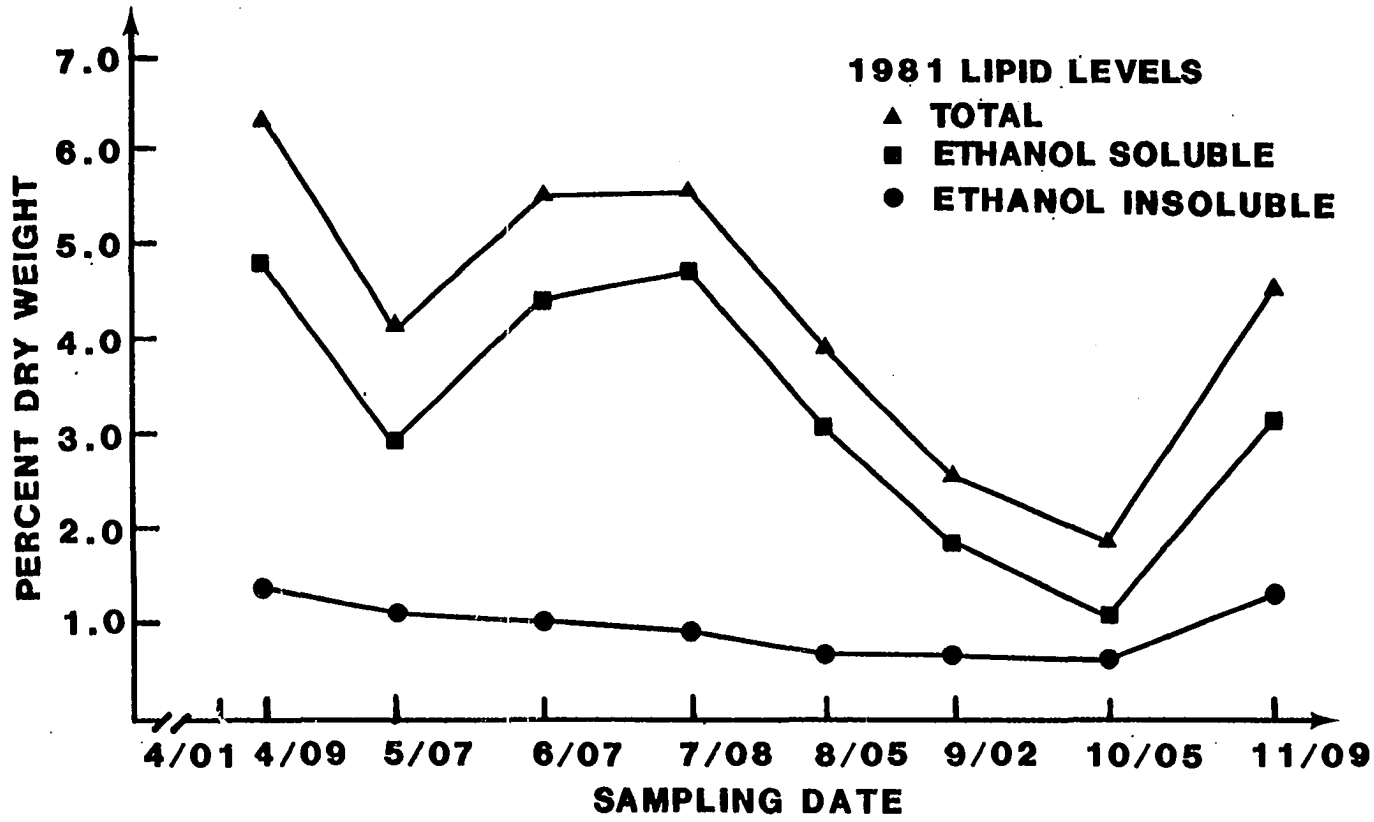

Figure 4. Seasonal hemp dogbane crown root lipid levels, Cumberland, Iowa, 1981

hardy. Fall tillage to expose crown and lateral root fragments to freezing temperatures did not prevent shoot emergence or promote root dehydration, except for sections laying on the soil surface. Even root sections that were only partially buried developed shoots the following spring. Lipid accumulation in hemp dogbane crowns may aid in cold tolerance as shown in quackgrass rhizomes (Stoller, 1977). Late fall lipid level increases might just reflect increased metabolic activity as hemp dogbane enters dormancy due to carbohydrate shifts generating metabolic wastes irrespective of cold tolerance, however.

Seasonal lipid and carbohydrate interactions

All three lipid variables were negatively correlated with TNC and starch values (see Table 10). Residue lipid correlations were not significant, but ethanol soluble and total lipid values revealed a possible inverse relationship of lipids with TNC and starch for 1980 and 1981. Reducing sugar levels show a fairly strong positive correlation with ethanol soluble and total lipids. This may simply be increased metabolic waste generated during peak activity periods as discussed for carbohydrate and cold tolerance. Overall lipid levels tend to decrease as starch accumulation reaches a plateau in the fall when metabolic activity decreases.

Table 10. Hemp dogbane correlation coefficients and significance levels for nonstructural carbohydrates and lipids for seasonal effects, Cumberland, Iowa, 1980-1981

Sampling date	Lipids	Nonstructural carbohydrate				
		Ethanol soluble				
		Reducing	Non-reducing	Total	Starch	Total
1980 season	Ethanol insoluble	0.37	0.40	0.61*	-0.33	-0.19
	Ethanol soluble	0.60*	-0.18	0.10	-0.53*	-0.49
	Total	0.58*	-0.02	0.26	-0.52*	-0.44
1981 season	Ethanol insoluble	0.30	0.55*	0.62*	-0.22	-0.09
	Ethanol soluble	0.59*	0.18	0.55*	-0.65**	-0.56*
	Total	0.57*	0.28	0.60*	-0.59*	-0.49

*,**Indicate significance at the 5% and 1% levels, respectively.

Further investigation is necessary to determine if the lipid pool may be interacting as a carbohydrate reserve. Significant involvement of latex with carbohydrate reserves is perhaps more plausible in articulated lacticifers that would better facilitate latex movement when needed. Apocynaceae are considered to be nonarticulated lacticifers (Metcalfe, 1967). Nonarticulated lacticifers appear more functionally apt for isolating substances from other systems, rather than setting up a network for transporting potential carbohydrate reserves.

Carbohydrate levels by crown and lateral root depth

Two crown and lateral root systems were analyzed for carbohydrate levels by depth (Table 11). Carbohydrate levels, particularly starch values, differed with depth. Sampling of one crown and vertical root to a depth of 81 cm revealed a general increase in starch levels to a maximum of 52.3% starch at 54 cm. Ethanol soluble carbohydrate levels generally remained constant with depth. Analysis of a crown root arising from a lateral at 32 cm revealed an increase of starch levels at 30 cm vs the top 5-7 cm of the crown root, but low levels of starch in the lateral proper. Reducing sugar levels remained constant but nonreducing sugar levels increased corresponding to a simultaneous decrease in starch in lateral root segments. This resulted in overall carbohydrate levels being only approximately 20% lower in the

Table 11. Nonstructural carbohydrate levels by depth of hemp dogbane crown and lateral roots, Cumberland, Iowa, 1981

Root section	Depth	Section diameter	Nonstructural carbohydrates				
			Ethanol soluble				
			Reducing	Non-reducing	Total	Starch	Total
	----(cm)-----		----------(% dry weight)----------				
Plant #1							
Crown	2	18	3.5	11.9	15.4	20.1	35.5
Ascending vertical	27	8	2.6	6.8	9.5	38.5	47.9
Ascending vertical	54	6	2.1	6.0	8.1	52.3	60.4
Ascending vertical	81	6	1.9	7.8	9.7	40.2	49.9
Plant #2							
Crown	5	15	2.9	9.2	12.1	15.6	27.7
Ascending vertical	30	6	3.0	9.0	12.0	39.4	52.0
Lateral branch	32	5	4.0	17.4	21.3	18.6	40.0
Descending vertical	36	5	4.4	16.9	21.3	19.6	40.9

laterals vs the ascending vertical root, despite the fact that starch values dropped approximately 50% in the lateral roots. Schultz and Burnside (1979b) also found increasing TNC with depth of hemp dogbane crown roots.

Crown roots in undisturbed situations are likely more important for absolute TNC levels available for regrowth. This is due to the increased crown mass from secondary growth relative to deeper vertical and lateral roots. This is not to discount the ability of lower roots to produce shoots in tilled situations.

Qualitative hemp dogbane crown root carbohydrate analysis

Paper and molecular sieve chromatography, as well as colorimetric analysis were used for qualitative determination of hemp dogbane crown root carbohydrates. Table 12 shows ethanol soluble carbohydrate levels. No significant differences by sampling date were found by Duncan's multiple range tests at the 5% level.

Sucrose was the most abundant carbohydrate present and accounted for most of the nonreducing sugar. The rest may be raffinose and occasionally stachyose as seen on paper chromatograms. Glucose was virtually absent in all samplings. Paper chromatogram spot densities compared to known standards indicated that maltose and a little fructose may account for part of the nonglucose reducing sugar values. Noncarbohydrate reducing groups may add to artificially high reducing

Table 12. Qualitative analysis of hemp dogbane ethanol soluble carbohydrates for dates reflecting seasonal total nonstructural carbohydrate maximums and minimums, Cumberland, Iowa, 1981

Sampling date	Plant development stage	Ethanol soluble carbohydrates[a]						
		Total	Reducing	Nonreducing	Sucrose	Glucose	Non-glucose reducing	Non-sucrose non-reducing
		(% dry weight)						
04/09/81	Dormant	9.15	2.12	7.02	6.42	0.13	2.00	0.60
07/08/81	Flowering	8.85	4.42	4.42	3.29	0.62	3.81	1.14
11/09/81	Dormant	11.98	3.75	8.22	7.96	0.25	3.49	0.26

[a]Duncan's multiple range tests revealed no significant differences between means at the 5% level.

sugar values as well. Although not significant, trends indicate a higher percentage of ethanol soluble carbohydrates are reducing sugars during flowering relative to dormant stages. This corresponds to seasonal carbohydrate levels as discussed earlier. Starch samples digested by α-amylase were mostly maltose with some glucose present.

An unidentified trailing spot on paper chromatograms occasionally appeared on November 1981 samples with an Rf glucose ranging from 0.33-0.60. Hough and Jones (1962) discussed possible ionization of 2-amino-2-deoxy-D-glucose with ethyl acetate: pyridine:water solvent systems of ratios different than those used here. When nonionized, this deoxyglucose chromatographed with a Rf glucose of 0.51 with solvent concentration ratios as used in this study. This sugar was not detected under ultraviolet light, assuming it was at concentrations allowing detection, by p-anisidine and periodate (Veiga and Chandelier, 1967).

Fructosans are common storage carbohydrates of perennial forage species (Smith, 1971) and some perennial dicotyledons, most notably Jerusalem artichoke (Helianthus tuberosus L.) (Hirst, 1957; Bacon and Edelman, 1951). Spot checks with the Roe resorcinol colorimetric test did not indicate fructosans to be a significant carbohydrate in hemp dogbane.

Established Hemp Dogbane Crown Root Carbohydrate and Lipid Levels in Response to Seedbed Tillage

Hemp dogbane crown root lipid and carbohydrate levels generally were not significantly altered by seedbed tillage. Root lipid levels were negatively correlated with carbohydrate levels across tillage practices. Carbohydrate levels averaged across tillages were consistent between years, with spring levels lower than those in the fall.

A summation of analysis of variance data is presented in Appendix A, Tables 25 and 26. By analysis of variance tests, only the 1981 spring and fall reducing sugar levels were significantly altered by seedbed tillage. Table 13 shows 1980 and 1981 spring and fall nonstructural carbohydrate levels. Hemp dogbane crowns and roots were dormant in all but the May 7, 1981 sampling date. On May 7, 1981, a few shoots had emerged in less severe tillage treatment areas, but this did not seem to affect total carbohydrate levels.

Duncan's multiple range tests show that, on November 6, 1980, fall chisel starch values were significantly lower than no tillage and fall disk values. These significances carried through in total carbohydrate levels as well, except for fall disk. No other carbohydrates were significantly altered by seedbed tillage in 1980 sampling dates.

May 1981 fall moldboard plow reducing sugar levels were significantly higher than all other tillage treatments. Lower nonreducing sugar and starch levels for the fall mold-

Table 13. Average hemp dogbane nonstructural carbohydrate levels by seedbed tillage at different sampling dates,[a] Cumberland, Iowa, 1980-1981

Seedbed tillage	1980 average nonstructural carbohydrates[b]				
	Ethanol soluble				
	Reducing	Nonreducing	Total	Starch	Total carbohydrates
	(% dry weight)				
		April 23			
No tillage	3.0a	4.9a	7.9a	26.4a	34.3a
Spring disk	2.9a	8.1a	11.0a	29.1a	40.1a
Fall disk	3.2a	5.3a	8.5a	28.9a	37.4a
Spring chisel	2.9a	2.9a	5.8a	23.6a	29.4a
Fall chisel	3.0a	2.7a	5.8a	27.7a	33.4a
Spring plow	2.9a	6.6a	9.5a	25.2a	34.7a
Fall plow	3.2a	2.7a	5.9a	13.5a	19.4a
Mean	3.0	4.8	7.8	24.9	32.7
		November 6			
No tillage	3.2a	6.1a	9.3a	39.3a	48.6a
Spring disk	3.4a	6.8a	10.2a	33.1ab	43.3ab
Fall disk	2.6a	4.1a	6.7a	40.2a	46.9ab
Spring chisel	2.9a	4.8a	7.7a	30.3ab	37.9ab
Fall chisel	2.8a	7.4a	10.3a	22.3b	32.6b
Spring plow	3.0a	7.3a	10.3a	29.1ab	39.4ab
Fall plow	3.5a	7.8a	11.3a	29.1ab	40.4ab
Mean	3.1	6.3	9.4	31.9	41.3
Year average	3.5	3.9	7.4	24.0	31.4

[a]April 23, 1980 = 1 tillage plus overwintering; November 6, 1980 = 2 tillage; May 7, 1981 = 2 tillage plus overwintering; November 5, 1981 = 3 tillages.

[b]Means within the same column and sampling date followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range tests.

1981 average nonstructural carbohydrates[b]				
Ethanol soluble				
Reducing	Nonreducing	Total	Starch	Total carbohydrates
(% dry weight)				
		May 7		
2.1b	5.7a	8.8ab	23.4a	31.2a
2.6b	3.5ab	6.1b	24.4a	30.6a
3.1b	5.3ab	8.4b	26.4a	34.7a
2.8b	6.2a	9.0ab	28.0a	37.0a
2.7b	5.5ab	8.2b	28.1a	36.3a
3.2b	4.8ab	8.0b	21.5a	29.5a
9.2a	2.8b	12.0a	15.8a	27.8a
3.8	4.8	8.6	23.8	32.4
		November 5		
3.7a	8.3a	12.0a	29.1ab	41.1ab
3.7a	6.3a	10.0ab	28.0b	38.0b
3.1ab	6.2a	9.3b	32.6ab	41.9ab
3.6a	7.3a	10.9ab	39.1a	50.0a
3.2ab	4.1a	9.3b	33.3ab	42.9ab
2.8b	6.9a	9.7ab	35.9ab	45.6ab
2.5b	6.1a	8.7b	38.9a	47.7ab
3.2	6.7	10.0	33.8	43.8
3.3	5.7	9.0	26.1	35.0

board plow treatment resulted in overall total carbohydrate levels that did not differ significantly by seedbed tillage, however. Fall moldboard plow total ethanol soluble carbohydrate levels were significantly higher than most other seedbed tillages, again reflecting the abnormally high reducing sugar levels with fall plow.

A higher percentage of total carbohydrates appears to be in more mobile forms in the May 1981 fall plow treatments. Expected fall moldboard plow total carbohydrate levels would be considerably lower than, for example, spring moldboard plow treatments if increased respiration and winterkill were to occur with fall tillage. The increased conversion of starch to smaller oligo- and monosaccharides involved with coldhardiness (Barr, 1940) may be a more plausible explanation for these observed differences on May 1981 moldboard plow treatments.

November 1981 moldboard plow reducing sugar levels were significantly lower than no tillage spring disk and spring chisel levels. Reducing sugar levels tended to be lower and starch levels higher with more severe tillage treatments. The November sampling date values indicate trends of an increased percentage of total carbohydrates as starch, contrary to the fall moldboard plow treatment in May 1981.

Spring reducing and total ethanol soluble carbohydrate levels were always higher than fall tillage levels. Starch

and total carbohydrate values did not show any fall versus spring tillage trends, however.

Means averaged across tillage treatments for ethanol soluble carbohydrate levels by each sampling date were generally consistent between years. Spring ethanol soluble carbohydrate levels were slightly lower than fall levels, except for the reducing sugar levels in 1981. Starch carbohydrate levels also were consistent between years. Fall sampling dates gave an approximate 22 and 30% increase in 1980 and 1981 respective starch levels compared to spring sampling dates. Spring versus fall sampling dates show a 21 and 26% respective increase in total carbohydrate levels.

Table 14 shows lipid levels of hemp dogbane in response to seedbed tillage. Duncan's multiple range tests reveal significant differences, but these appear to be of little applicability. All but November 1980 ethanol insoluble lipids were negatively correlated with starch and total carbohydrate levels. Only the April 1980 correlations appear to be of any significance as was discussed in the seasonal carbohydrate and lipid section (Table 15).

Herbicidal Control of Hemp Dogbane

Broadcast herbicide and broadcast herbicide by application date interactions were significant by analysis of variance tests. Application date was not significant (Appendix

Table 14. Average hemp dogbane percent[a] dry weight lipid levels by seedbed tillage at different sampling dates, Cumberland, Iowa, 1980-1981

Seedbed tillage	1980 average lipid levels[b] Ethanol soluble	Ethanol insoluble	Total	1981 average lipid levels[b] Ethanol soluble	Ethanol insoluble	Total
	(% dry weight)					
	April 23			May 7		
No tillage	1.91b	1.34ab	3.28b	2.90bc	1.21a	4.11bc
Spring disk	2.71ab	1.45a	4.16ab	5.71a	1.55a	7.26a
Fall disk	1.50b	1.15abc	2.65b	3.17bc	1.42a	4.59bc
Spring chisel	0.98b	0.93c	1.91b	1.55c	0.96a	2.50c
Fall chisel	2.41ab	0.96bc	3.37b	2.12bc	1.11a	3.22bc
Spring plow	2.73ab	1.18abc	3.92ab	3.28bc	0.89a	4.17bc
Fall plow	4.77a	1.34ab	6.11a	4.16ab	1.13a	5.29ab
Mean	2.44	1.19	3.63	3.27	1.18	4.45
	November 6			November 5		
No tillage	2.57a	1.20ab	3.77a	3.22a	1.33a	4.55a
Spring disk	2.51a	0.67c	3.18a	2.07abc	1.33a	3.43ab
Fall disk	1.63a	0.77bc	2.40a	2.01abc	1.31a	3.32ab
Spring chisel	2.11a	1.23a	3.34a	2.25abc	0.89a	3.14ab
Fall chisel	5.82a	0.85abc	6.67a	1.57bc	1.05a	2.62bc
Spring plow	2.40a	0.90abc	3.31a	2.69ab	1.28a	3.98ab
Fall plow	5.07a	0.54c	5.60a	1.12c	0.45b	1.57c
Mean	3.16	0.88	4.04	2.13	1.09	3.23
Year average	1.98	1.11	3.09	3.27	1.01	4.28

[a]April 23, 1980 = 1 tillage plus overwintering; November 6, 1980 = 2 tillages; May 7, 1981 = 2 tillages plus overwintering; November 5, 1981 = 3 tillages.

[b]Means within the same column and sampling date followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range tests.

Table 15. Hemp dogbane correlation coefficients and significance levels for nonstructural carbohydrates and lipids by seedbed tillage on various sampling dates, Cumberland, Iowa, 1980-1981

Sampling date	Lipids	Nonstructural carbohydrates				
		Ethanol soluble				
		Reducing	Non-reducing	Total	Starch	Total
04/23/80	Ethanol insoluble	-0.14	0.47	0.40	-0.01	0.10
	Ethanol soluble	0.02	-0.20	-0.18	-0.63*	-0.56*
	Total	0.00	-0.12	-0.11	-0.59*	-0.51
11/05/80	Ethanol insoluble	-0.11	-0.22	-0.21	0.24	0.18
	Ethanol soluble	0.40	0.60*	0.59*	-0.40	-0.21
	Total	0.40	0.59*	0.59*	-0.38	-0.19
04/09/81	Ethanol insoluble	0.05	-0.33	-0.18	-0.14	-0.43
	Ethanol soluble	0.31	-0.66*	-0.10	-0.37	-0.09
	Total	0.28	-0.64*	-0.12	-0.35	-0.10
11/09/81	Ethanol insoluble	0.28	0.21	0.27	-0.39*	-0.32
	Ethanol soluble	0.35	0.44*	0.50**	-0.22	-0.07
	Total	0.40*	0.45*	0.52**	-0.31	-0.16

*,**Indicate significance at the 5% and 1% levels, respectively.

A, Table 27). Table 16 shows that glyphosate alone and in combination worked equally well applied at early flower or pod set stages of growth. 2,4-D amine alone provided more effective control at early flower, but 2,4-D with dicamba was more effective at the early pod stage of growth.

Hemp dogbane regrowth was significantly reduced one year following glyphosate application through selective equipment. Location differences were significant, but herbicide by location interactions were not by analysis of variance tests (Appendix A, Table 28). Location significance may be due to less crop-weed height differential at the Swanson test site reducing glyphosate coverage of hemp dogbane.

All methods gave satisfactory results with the exception of the pipe wick applicator at 2 mph (Table 17). Increasing ground speed to 4 mph appears to have improved weed contact with the ropes without the rate of herbicide wick flow becoming limiting. Selective applications with spray streams gave more soybean injury through increased splattering when compared to passive flow systems. Crop canopy height prevented treatment of shorter hemp dogbane shoots. Although control with glyphosate in selective applicators was generally good, more complete regrowth suppression may have been possible with better coverage as seen with the broadcast glyphosate application on hemp dogbane.

Limited uptake of glyphosate (Wyrill and Burnside, 1976)

Table 16. Hemp dogbane control in corn with preharvest broadcast herbicide applications, Ames, Iowa, 1979

Herbicide treatment	Rate	Treated 6/21/79[a]	Treated 9/11/79
	(lb a.i./A)	(% control on 5/28/80)	
Dicamba + 2,4-D	.25 + 1.0	30	89
Dicamba	.25	88	71
Dicamba	1.0	69	-
Glyphosate + dicamba	1.5 + .25	-	87
2,4-D amine	1.0	97	62
Glyphosate	1.5	85	93
Glyphosate	2.25	88	89
Glyphosate	3.0	92	90
Glyphosate + 2,4-D	1.5 + 1.0	83	85
Check	-	0	0
Mean		68.2	71.6
Least significant difference	1% level		32.9
	5% level		24.7

[a]6/21/79 dogbane at late bud to early flowering stage of growth; 9/11/79 dogbane at late flowering to pod set stage of growth.

Table 17. Hemp dogbane control and soybean injury using glyphosate in a box-type recirculating sprayer, broadcast recirculating sprayer, straight pipe rope wick and Bobar rope wick applicator at Ames, Iowa, 1979

Applicator design	Rate[a]	Speed	McCay Farm control	Swanson Farm control	Average weed control	Average soybean injury
	(% v/v)	(mph)		(%)		
Control	-	-	0	0	0	0
Pipe rope wick	33	2	60	53	56	0
Pipe rope wick	33	4	80	-	80	0
Pipe rope wick 2 passes	33	2	77	65	71	0
Bobar rope wick	33	2	75	65	70	0
Bobar rope wick	33	4	83	63	73	0
Glove treated	10	-	-	70	70	0
Box RCS	7.5	5	75	65	70	31.5
Broadcast RCA	7.5	5	83	45	64	11.5
Location mean			66.2	54.1	-	-
Least significant difference			1% level		31.0	
			5% level		22.5	

[a]Glyphosate rate expressed as percent Roundup commercial formulation. Nalco 2151 defoamer used at 2 oz/100 gal with recirculating sprayers.

may prevent selective applicator treatments from equalling broadcast application even if all plants were at treatable heights. Early flower stage of hemp dogbane growth in the selective applicator and broadcast herbicide treatments and the pod set-leaf yellowing stage of broadcast treatment all appear to have translocated to underground roots. The pod set stage of broadcast herbicide application generally worked as well as early flower treatments despite laboratory data indications that crown root carbohydrate storage may be reaching a seasonal plateau at this time. If herbicide translocation was passive movement with phloem assimilates, reduced regrowth control of hemp dogbane would be expected at these later stages of growth. Results here contradict the findings of Barnes and Brenchley (1972) that glyphosate control of hemp dogbane was reduced when applied at late flower as opposed to early flower stages of development.

Photoperiod Response of Hemp Dogbane Crown Roots in the Growth Chamber

Hemp dogbane growing under natural light in the greenhouse was noted to enter dormancy in the fall and break dormancy in the spring despite the temperature remaining a constant 25°C. Plants started from seeds in April 1980 established and were dormant 203 days later. Left in the greenhouse and watered as necessary, these crowns broke dormancy with the first emergence noted on March 31, 1981,

162 days after entering dormancy. Emergence was underway in 35% of the pots within 20 days. This second year of growth entered dormancy again 200 days later in late October, with leaf yellowing beginning around September 26, 1981.

These dormant hemp dogbane root systems were placed in growth chambers on January 14, 1982. Emergence was noted 41 days later on February 23 in the 18-hr daylength treatment. Thirty-seven percent of the pots in the 18-hr daylength chamber had shoots emerging by February 25. Table 18 shows the response of the two-year-old dormant hemp dogbane roots to photoperiod length. Significantly more shoots emerged in the 18-hr photoperiod than in either of the 10- and 14-hr photoperiods. Six of the eight replications had shoots emerge in the 18-hr daylength treatments for an average of 2.1 shoots per pot. Only one replication for an average of 0.2 shoots per pot emerged in each of the 10- and 14-hr daylength periods. Crown buds exposed at the soil surface failed to elongate in the 10- and 14-hr photoperiods. Plant height was greater and morphological development more advanced in the 18-hr daylength period. Two plants reached the early flower stage of development in the 18-hr daylength, whereas all plants remained as vegetative stages with shorter daylength periods. All pots had viable crown and lateral roots when the study was ended. Analysis of variance data are summarized in Appendix A, Table 29.

Table 18. Response of two-year-old dormant hemp dogbane roots to photoperiod length after 77 days in the growth chamber, Ames, Iowa, 1982

Daylength	Days to first emergence[b]	Average (8 reps)[a] Shoots	Height	Morphological development
(hr)		(no./pot)	(mm)	
10	42	0.2b	23.1b	Vegetative
14	40	0.2b	23.4b	Vegetative
18	38	2.1a	160.5a	Vegetative to early flower

[a]Means followed by the same letter within the same column do not differ significantly at the 5% level according to Duncan's multiple range tests.

[b]Number of days after dormant crown exposure to various photoperiods.

Photoperiod response can play a role in hemp dogbane root bud dormancy break. In this study, crown roots were intact with the crown buds at or near the soil surface. A photoperiod response would not be expected to regulate the dormancy break of adventitious buds on root segments that are not exposed to, or connected with, plants at the soil surface. An example would be crown root segments that are disrupted and buried by a fall plow tillage treatment. These segments remain dormant until the following spring when they were observed to break dormancy and establish new plants from all plow layer depths. A photoperiod response

governing this dormancy break is unlikely since light penetrates only the upper 2 cm of the soil surface (Taylorson, 1972).

One plant in the 18-hr daylength photoperiod emerged from a bud that was 4.5 cm below the soil surface (below the expected light penetration level). Another crown that was exposed at the soil surface originated 5 cm away on the same lateral root and could have transmitted the photoperiod stimulus to the buried bud. Light regulation of shoot emergence originating from adventitious root buds near the soil surface, as discussed for field bindweed (Bonnett, 1972), could not be substantiated for hemp dogbane as shoots always developed from crown buds before arising from adventitious buds. Some shoots did develop from crown buds that were not visible at the soil surface, however.

Soil temperatures may well be the dominant factor governing dormancy of hemp dogbane populations *in situ*, especially where tillage disrupts and isolates portions of the buried root system. Photoperiod daylengths as measured from sunrise to sunset at 42^{o} latitude N are only 14 hr (List, 1951) by the end of April when dogbane emergence has been noted. Daylength on June 25th, the longest day, is only 15 hr and 15 min. This would indicate little significance of the photoperiod lengths observed in this study governing winter resting stage dormancy break of hemp

dogbane in the field. Cumulative photosynthetically or phytochrome active irradiance flux (duration and intensity of active light periods) could possibly alter emergence in field situations comparable to these growth chamber observations, however, and deserves further investigation.

CONCLUSIONS

Intensive seedbed tillage coupled with 1-2 row cultivations per year did not significantly reduce an established stand of hemp dogbane at Cumberland, Iowa. The number of tillage treatments and the necessity of tillage throughout the season as used to eradicate hemp dogbane in Kansas (Timmons and Bruns, 1951) are not compatible with current crop production practices in Iowa.

Perennial weeds established at a faster rate with reduced tillage systems at Nashua, Iowa. All tillage systems had an increase in perennial weed populations however. Selective applicator equipment or proper timing of postemergence broadcast herbicide applications did reduce hemp dogbane infestation levels.

Examining the root system and carbohydrate levels of hemp dogbane supported the findings that seedbed tillage and 1-2 row cultivations would not reduce established hemp dogbane populations. Seasonal carbohydrate trends aid in proper herbicide application timing, but herbicidal control still appeared adequate when carbohydrate buildup in hemp dogbane crown roots appeared to level off. The possibility of lipids interacting with carbohydrate reserves is not strongly supported, and would require studies directed specifically towards that purpose to elucidate it further.

Soil warming in the spring was generally slower with

lesser tillage practices. Hemp dogbane emergence initiated uniformly throughout all seedbed tillage treatments, except for moldboard plow treatments despite this temperature difference. Photoperiod daylength did affect hemp dogbane winter dormancy break in growth chamber tests. Applying light effects to the field situation would require observing light intensity and quality similar to field conditions as well as photoperiod length. Soil temperature, daylength, and time requirements for innate dormancy shifts may all interact to regulate hemp dogbane winter dormancy break.

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APPENDIX A. STATISTICAL SUMMATION FOR DATA REPORTED

Statistical Analysis of Established Hemp Dogbane Populations in Response to Soil Tillage

Hemp dogbane weed populations tend to be nonuniform across test areas relative to some annual weeds and finer rooted or rhizomotous perennial weed species. Because of this nonuniformity in the base population, several statistical means were used to analyze the data. Analysis of variance tests performed on the data using the percentage population change over the 1978 base year counts were not satisfactory due to large differences in the initial population levels creating spurious results.

Analyses were then performed on the change in population over the 1978 base year as an analysis of covariance with the base year counts as the covariant. Least squares (LS) means for the tillage, cultivation, and tillage by cultivation interaction effects were estimated from the formula:

$$\text{LS mean} = X_{i.} - b(Y_{i.} - \bar{Y})$$

$X_{i.}$ = the ith tillage mean in 1980 (or 1981)

$Y_{i.}$ = the ith tillage 1978 base year mean

$\bar{Y}$ = overall 1978 base year mean

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The efficiency of the change in population versus the covariance analysis was judged by comparing corresponding error

mean squares. Covariance analysis was always more efficient than the change in population analysis.

Large numbers of treatments included in a model can sometimes obscure differences between two or more individual treatments due to increased error associated with these treatments. Data for only the continuous spring tillage treatments were isolated and analyzed by the methods previously mentioned. Evaluating only continuous spring tillages did not improve the precision of testing (did not reduce the mean square enough to compensate for the loss in degrees of freedom) and did not change any of the significance determinations for the treatment effects. Change in population data was also analyzed for contrast effects and Duncan's multiple range testing. Covariance analysis treatments LS means were compared using the student's t-test.

Because some of the rotational seedbed tillages did not differ until the third year, the comparison of 1980 counts versus the base year analysis is an unbalanced design. The chisel plow and moldboard plow treatments, in effect, have extra replications. The analysis for change in population and covariance using 1980 data were run as a general linear regression model with an unbalanced randomized split plot design.

Orthogonal contrasts were performed on the change in population data which revealed no difference in severe versus

light tillage. Severe tillage was that of chisel and moldboard plowing and light tillage was that of no tillage and tandem disking. Chisel plow versus moldboard plow did show significant differences in population change when comparing 1980 to the base year. The overall test period of 1981 compared to 1979, however, showed no significance. No tillage versus disk treatments did not show significance in any of the year-by-year contrast comparisons.

Table 19. Summation of general linear model regression analysis as change in population and covariance analysis for seedbed tillage and row cultivation effects on hemp dogbane populations, Cumberland, Iowa, 1979-1981

	1980 with 1978 base year				1981 with 1978 base year			
	Δ population		Covariance		Δ population		Covariance	
Source	d.f.	MS	d.f.	MS	d.f.	MS	d.f.	MS
Covariate	-	-	1	12938175**	-	-	1	454.72
Rep	3	963.34	3	939.90	3	711.63	3	385.72
Tillage	11	867.91	11	786.94	11	556.82	11	201.88
Rep x tillage (Error A)	33	648.11	33	621.04	33	405.10	33	329.47
Cultivation	1	371.77	1	421.51	1	3360.12**	1	2699.44**
Tillage x cultivation	11	310.31	11	286.84	11	262.57	11	180.55
Residual (Error B)	76	294.43	75	293.90	76	256.57	75	138.61

**Denotes F-test significance at the 1% level.

Table 20. Analysis of variance summation for hemp dogbane split-plot evaluation of ground cover, flowering, plant height, and maturation, Cumberland, Iowa, 1981

Source	d.f.	Mean squares			
		Ground cover (%) 6/20/81	Flowering (%) 6/30/81	Plant height (cm) 6/20/81	Maturation (%) 10/05/81
Rep	3	5218.2**	361.6	1471.0*	2983.9**
Tillage	16	1709.9*	1115.2**	1526.5**	1326.1*
Rep x tillage (Error A)	48	814.2	360.4	470.7	584.0
Cultivation	1	11324.1**	20605.0**	120.5	2559.6**
Cultivation x tillage	16	290.7	697.0	62.4	40.4
Residual (Error B)	51	271.0	456.6	55.8	41.5

*,**Indicate F-test significance at the 5% and 1% levels, respectively.

Table 21. 1980 general linear models regression and 1981 analysis of variance summations for whole plot evaluation of hemp dogbane ground cover, flowering, plant height, and pod set, Cumberland, Iowa, 1980-1981

		Mean squares				Mean squares			
Source	d.f.	Ground cover (%) 7/09/80	Flowering (%) 6/24/80	Plant height (cm) 7/09/80	d.f.	Ground cover (%) 7/08/81	Flowering (%) 7/08/81	Plant height (cm) 7/08/81	Pod set (%) 8/05/81
Rep	3	1224.9*	1501.2**	1990.1*	3	2382.5**	542.5	1576.4*	3320.7*
Tillage	11	1775.3**	3928.6**	1229.0	16	1026.0*	1224.6**	560.9	349.5
Residual	53	404.57	265.12	719.33	48	530.16	208.41	484.44	787.48

*,**Indicate significance at the 5% and 1% levels, respectively.

Table 22. Analysis of variance summation for crown and lateral root average diameter and depth with different seedbed tillages, Cumberland, Iowa, 1981

		Mean squares			
		Crown roots		Lateral roots	
Source	d.f.	Diameter	Depth	Diameter	Depth
Rep	3	33.75	22.23	2.50	120.56
Seedbed tillage	3	52.08[a]	17.23	5.33	77.56
Residual	9	16.92	26.11	6.72	88.45

[a]Probability of exceeding F-value = 8.31%. No observation means were significant at the 5% and 1% levels.

Table 23. Analysis of variance summation for perennial weed establishment in response to seedbed tillage and crop rotation, Nashua, Iowa, 1980-1981

Sampling date	Source	d.f.	Hemp dogbane	American germander
6/19/80	Rep	2	32435771	41819763
	Crop rotation	2	25826090	59596957
	Rep x crop rotation (Error A)	4	12325493	23172137
	Tillage	3	11604270	10228745
	Tillage x crop rotation	6	11604270	15861212
	Residual (Error B)	18	5812823	12881908
6/25/81	Rep	2	19739112	23561728
	Crop rotation	2	8522920	23095394
	Rep x crop rotation (Error A)	4	12958001	17752401
	Tillage	3	5461762	10117699
	Tillage x crop rotation	6	7123973	6267250
	Residual (Error B)	18	4841641	7586198

*,**Indicate F-test significance at the 5% and 1%, levels, respectively.

Weed species mean squares				
Field bindweed	Yellow nutsedge	Common milkweed	Canada thistle	Total
240236	3259644	10866	1164	88518265
595018	2190308	3382	3382	78159838
81779*	2518339	16577	887	30308557
10398	1844730	29489	807	50398626
84840	1368342	4909	844	17305647
52985	1417674	13565	1718	18959578
183259	659018	14360	91537	83981243
1525875	429427	499	85882	22716383
305678	392724	3382	136252	67459814
75255	648385*	20551**	131561	28123732
414938*	226554	3308	113135	25074969
153122	193992	3650	119277	21203013

Table 24. Contrasts and analysis of variance mean squares for hemp dogbane crown root carbohydrate and lipid levels by seasonal effects, Cumberland, Iowa, 1980-1981

Source	Nonstructural carbohydrate mean squares					Lipid level mean squares		
	Ethanol soluble							
	Reducing	Non-reducing	Total	Starch	Total	Ethanol soluble	Ethanol insoluble	Total
				1980				
Month 4 vs 5	0.98*	0.71	3.37	310.13**	248.86*	1.11	0.07	1.37
Months 4-5 vs 6	3.59**	21.72	7.65	35.87	76.65	0.07	0.06	0.26
Months 4-6 vs 7	3.55**	15.14	4.03	67.29	104.25	0.01	0.13	0.07
Months 4-7 vs 8	7.21**	2.88	19.22	300.02**	167.37	2.78*	0.65**	6.11*
Months 4-8 vs 9	7.30**	0.09	5.76	673.71**	554.91	0.83	0.07	1.37
Months 4-9 vs 10	0.52	26.01	16.17	375.34**	556.55**	0.05	0.01	0.02
Error mean square	0.15	4.88	5.08	17.14	34.75	0.23	0.02	0.30
Trt mean square	3.86**	11.09	9.36	293.72**	284.77*	0.81	0.15*	1.54*
Rep mean square	0.00	1.51	1.38	19.28	9.83	0.00	0.12	0.14
				1981				
Month 4 vs 5	0.96	1.75	0.12	132.28	140.32*	3.67**	0.06	11.03*
Months 4-5 vs 6	21.44**	1.97	10.41	193.89*	114.44*	0.32	0.05	0.27
Months 4-6 vs 7	0.34	3.65	1.77	332.11**	382.41**	0.69	0.15	0.47
Months 4-7 vs 8	1.63	1.24	5.72	1.33	12.56	1.74*	0.37	8.79*
Months 4-8 vs 9	9.42**	0.94	16.33	579.66**	401.41**	7.77**	0.21	25.05**
Months 4-9 vs 10	5.64*	0.00	5.43	455.93**	361.80**	9.69**	0.36	32.67**
Months 4-10 vs 11	0.50	15.47	21.54	20.68	84.44	0.01	0.24	0.39
Error mean square	0.75	3.62	4.40	23.78	18.38	0.19	0.07	0.42
Trt mean square	5.70**	3.57	8.76	245.12**	213.91**	3.41**	1.44	4.74**
Rep mean square	0.27	0.45	1.41	8.81	17.27	1.17*	0.02	1.50

*,**Indicate F-test significance at the 5% and 1% levels, respectively.

Table 25. Analysis of variance summation for hemp dogbane nonstructural carbohydrate levels as affected by seedbed tillage sampled on various dates, Cumberland, Iowa, 1980-1981

		1980 nonstructural carbohydrate mean squares				
		Ethanol soluble				
Source	d.f.	Reducing	Nonreducing	Total	Starch	Total
		April 23, 1980				
Rep	1	0.02	1.16	0.87	93.19	112.06
Tillage	6	0.04	8.87	8.42	58.68	90.45
Residual	6	0.58	4.79	7.85	76.22	115.06
		November 6, 1980				
Rep	1	0.02	1.21	1.51	0.00	1.66
Tillage	6	0.20	4.00	5.30	78.47	60.01
Residual	6	0.36	7.10	9.66	36.19	35.11

*,**Indicate F-test significance at the 5% and 1% levels, respectively.

	1981 nonstructural carbohydrate mean squares				
	Ethanol soluble				
d.f.	Reducing	Nonre-ducing	Total	Starch	Total
		May 7, 1981			
1	0.82	0.01	0.62	7.13	3.55
6	11.46**	3.07	6.14	38.37	25.58
6	0.93	1.19	1.59	46.69	35.06
		November 5, 1981			
3	0.67	12.38**	15.50**	32.10	18.48
6	0.87*	2.60	5.14	77.46	68.77
18	4.07	2.21	2.26	41.21	44.27

Table 26. Analysis of variance summation for hemp dogbane lipid levels as affected by seedbed tillage sampled on various dates, Cumberland, Iowa, 1980-1981

Source	1980 lipid mean squares				1981 lipid mean squares		
	d.f.	Ethanol soluble	Ethanol insoluble	Total	d.f.	Ethanol soluble	Ethanol insoluble	Total
		April 23				May 7		
Rep	1	1.38	0.016	1.70	1	0.59	0.026	0.86
Tillage	6	2.96	0.079	3.55	6	3.73*	0.112	4.71*
Residual	6	1.05	0.022	1.02	6	0.64	0.078	0.99
		November 6				November 5		
Rep	1	7.77	0.242*	5.27	3	0.881	0.004	0.91
Tillage	6	5.16	0.133*	4.63	6	1.911	0.432**	3.66**
Residual	6	2.84	0.028	3.05	18	0.804	0.074	0.77

*,**Indicate F-test significance at the 5% and 1% levels, respectively.

Table 27. General linear models regression summation for herbicidal hemp dogbane control with broadcast herbicide treatments and application date, Ames, Iowa, 1979-1980

Source	d.f.	Mean squares
Rep	3	165.16
Herbicide treatment	9	5791.34**
Application date	1	33.06
Herbicide treatment x application date	7	1401.78**
Residual	51	301.94

**Denotes F-test significance at the 1% level.

Table 28. General linear models regression summation for hemp dogbane control using glyphosate in selective applicators, Ames, Iowa, 1979-1980

Source	d.f.	Mean squares
Rep	1	750.78
Herbicide treatment	9	845.06*
Location	1	1056.25*
Herbicide treatment x location	7	146.85
Residual	15	222.45

*Denotes F-test significance at the 5% level.

Table 29. Analysis of variance summation for the number of shoots and shoot height of hemp dogbane under different photoperiods, Ames, Iowa, 1982

Source	d.f.	Mean squares: Number of shoots emerged	Mean squares: Shoot height
Rep	7	2.76	50233.62
Photoperiod	2	9.38*	12235.90**
Residual	14	2.33	6768.96

*,**Indicate F-test significance at the 5% and 1% levels, respectively.

APPENDIX B. SOIL TEMPERATURE DATA

Table 30. Soil temperatures by seedbed tillage and tillage depth in the established hemp dogbane study, Cumberland, Iowa, 1980-1981

Seedbed tillage	depth	Average monthly soil temperatures: April 15-31, 1980	May 1-31, 1980	April 10-30, 1981	May 1-31, 1981
	(cm)	----------(°C)----------			
No tillage	10.16				
Average		11.41	15.92	12.16	14.32
Maximum		13.82	18.19	14.25	16.49
Tandem disk	10.16				
Average		12.69	16.45	13.42	15.91
Maximum		16.58	19.21	16.82	20.61
Chisel plow	10.16				
Average		12.54	17.11	13.42	16.08
Maximum		17.17	20.90	17.67	20.78
Moldboard plow	10.16				
Average		12.60	17.34	14.05	16.48
Maximum		18.10	21.23	17.70	22.01
No tillage	30.48				
Average		10.42	13.90	11.01	13.58
Maximum		10.97	14.21	11.59	14.08
Moldboard plow	30.48				
Average		10.86	15.36	12.15	15.19
Maximum		11.56	15.85	12.18	16.77

APPENDIX C. NOTES ON HEMP DOGBANE CROWN ROOT ANATOMY

Free-hand cross sections of hemp dogbane crown roots were stained in safranin-O and chlorazol black-E and examined under a light microscope. Cross-sectional anatomy showed an internal parenchyma tissue (pith), internal phloem bundles, 2-3 secondary xylem rings, the cambium, secondary phloem, parenchyma tissue (cortex), and the periderm consisting of a cork cambium (phellogen) and cork tissue (phellum). Numerous lacticifers were scattered throughout the external phloem and parenchyma tissue. Rays of parenchyma tissue traversed the xylem and phloem tissue. All parenchyma tissue appears very heavily laden with starch granules. Primary xylem and phloem were not discernible, but a few scattered bundles of collenchyma were present on the periphery of the secondary phloem. The xylem tissue appears to be vessel members with simple pits.